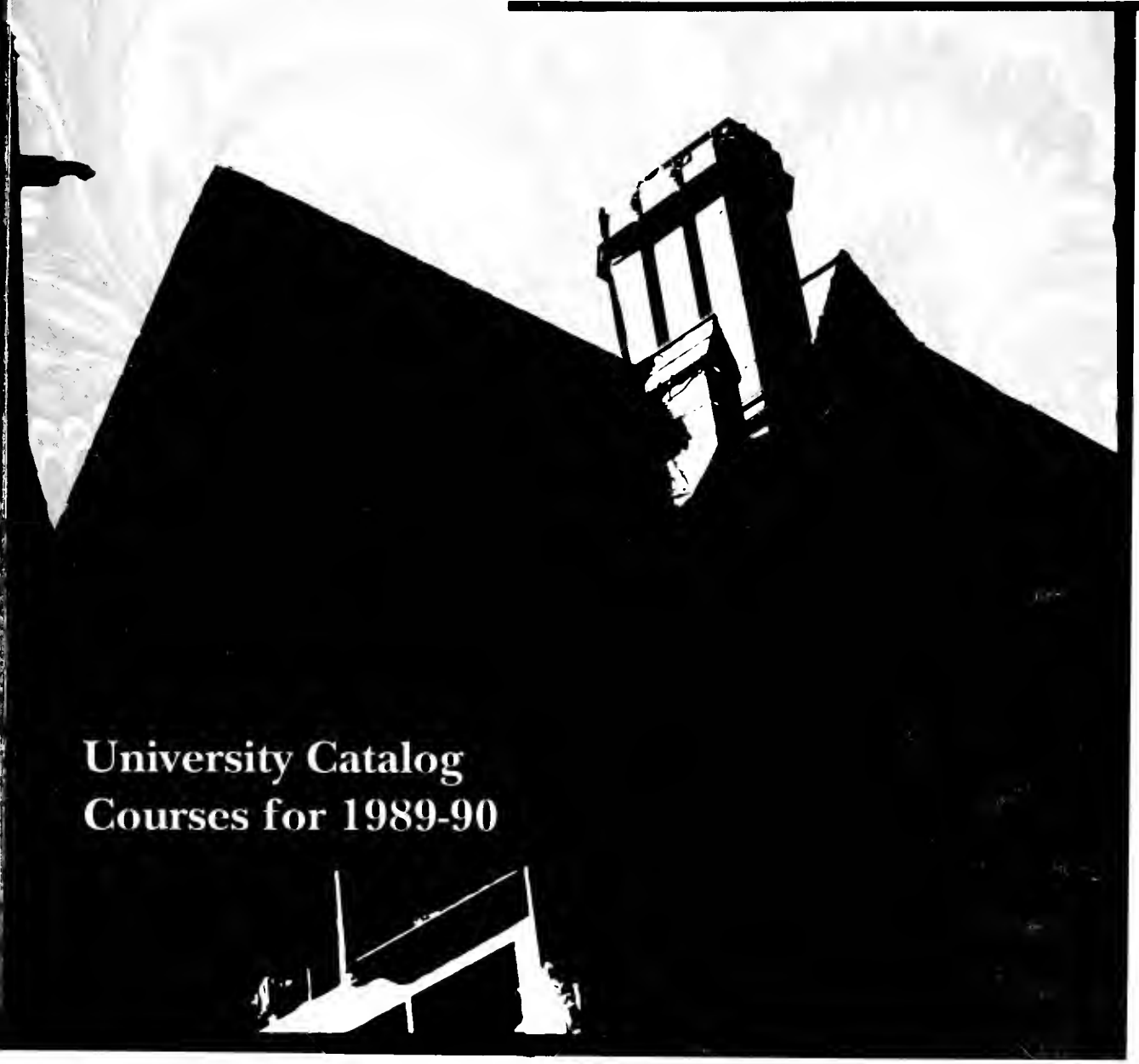
# LEHIGH UNIVERSITY

## Perspectives For A Lifetime Of Enrichment



## University Catalog Courses for 1989-90

# LEHIGH UNIVERSITY

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*Editorial coordination*

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How we approach life, how we interpret what we encounter in life, how we judge accomplishment or failure — all involve perspective.

As Lehigh enters its 125th year in 1990, the perspective of its educational mission remains unchanged — the University's first order of business is and always has been to provide students with a broad education for a useful life through its four colleges of Business and Economics, Education, Engineering and Applied Science, and Arts and Science.

But much about the University has changed since its founding, as it builds toward a perspective of leadership in an ever changing nation and world.

Today, Lehigh has grown to 1,600 acres. The university has 130 buildings. Its enrollment is 6,500. An expanding campus has also seen new facilities, including the Fairchild-Martindale Library and computing complex, the Sherman Fairchild Center for Physical Sciences, The Mohler Laboratory for Industrial and Manufacturing Systems Engineering, the razing of Taylor Stadium and the beginning of construction of the Rauch Business Center, and the Murray Goodman Stadium.

From the perspective of its alumni, Lehigh has served them well. Not only do Lehigh graduates captain or play leadership roles in many of America's great companies and corporations, but they also support their alma mater with a record of giving second in the nation among major universities.

Lehigh's campus offers its students unique perspectives of enrichment. From the physical beauty of its campus, to the historical richness of the Bethlehem community; from the enlightenment of the classroom and a distinguished and caring faculty, to the activity and warmth of the social environment; from the opportunities to explore many academic disciplines, to the resources for focusing on in-depth study and research.

The opportunities described in the pages of this edition of Lehigh's course catalog, combined with the environmental experiences of the University's South Mountain campuses can truly offer you a unique perspective for a lifetime of enrichment.

# LEHIGH UNIVERSITY

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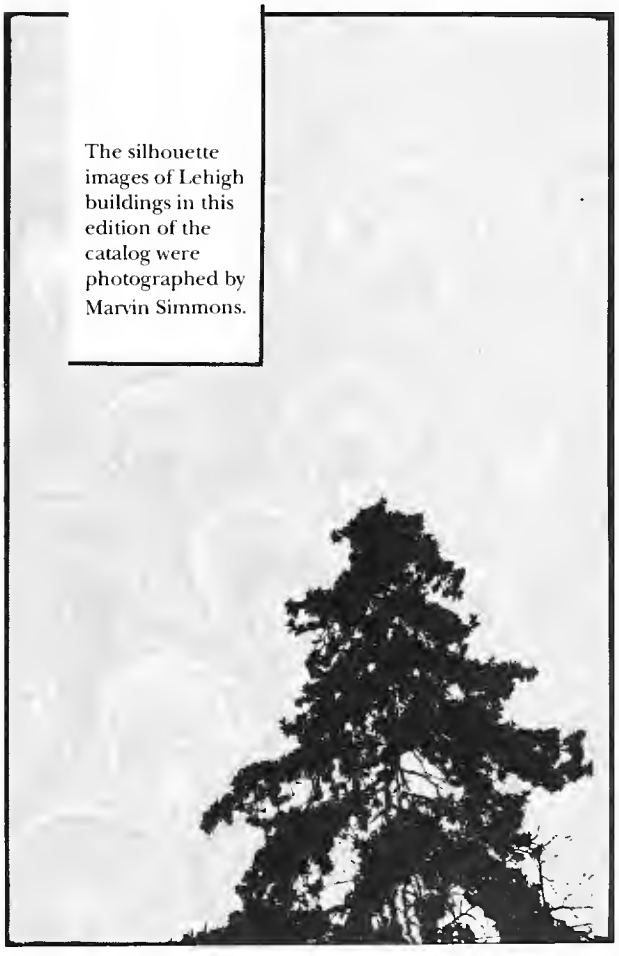
Academic Calendar—*inside back cover*


The silhouette images of Lehigh buildings in this edition of the catalog were photographed by Marvin Simmons.



# Major Subject Areas

The university offers the following undergraduate major programs. While most of these programs are offered as majors within a specific academic department, in some cases subjects transcend departmental lines or are emphases within a major program. Minors are available in virtually all major programs. Programs that are offered only as minors are described under the entries for individual colleges in Section III, Academic Programs in the Colleges, and under individual departments in Section V, Descriptions of Courses. Graduate programs are offered in many of the subjects listed. These are described in Section IV, Graduate Study and Research.

Accounting
American Studies
Applied Science
Architecture
Art
Arts/Engineering
Behavioral and Neural Biology
Biochemistry
Biology
Chemical Engineering
Chemistry
Civil Engineering
Civil Engineering/Geological Sciences
Classical Civilization
Classics
Cognitive Science
Computer Engineering
Computer Science
Economics
Electrical Engineering
Electrical Engineering/Engineering Physics
Engineering/Master of Business Administration
English
Environmental Sciences and Resource Management
Finance
Foreign Careers
French
Fundamental Sciences
Geological Sciences
Geophysics
German
Government
History
Industrial Engineering
International Relations
Journalism
Journalism/Science Writing
Management
Marketing
Materials Science and Engineering
Mathematics
Mechanical Engineering
Engineering Mechanics
Molecular Biology
Music
Natural Science
Philosophy
Physics
Engineering Physics
Predental Science
Premedical Science
Psychology
Religion Studies
Science, Technology and Society
Social Relations
Spanish
Statistics
Theater
Urban Studies

# I

## Information of General Interest

*"A Lehigh education is a lot like a climb up South Mountain. It doesn't matter which path you take; when you reach the top you'll have a broader view, a healthy thirst, and a downhill road before you. Don't go to a flat school."*
– Michael Butler, Lehigh graduate student.

# I.

# Of General Interest

This section includes information related to admission, accreditation, advanced placement, transfer students, tuition and fees, financial aid, academic regulations, campus life, and student services. Similar information for graduate students may be found in Section IV. The university's history, biographies of its presidents, descriptions of its buildings, and campus maps are found in Section VI.

## Accreditation

Lehigh University is accredited by the Middle States Association of Colleges and Schools.

The undergraduate and master's programs in business administration are accredited by the American Assembly of Collegiate Schools of Business. In 1985, the assembly gave the college continuing accreditation for ten years in these programs, and also granted accreditation of the college's undergraduate program in accounting. Lehigh is among approximately fifty schools among the 1,200 offering business degrees that received accreditation for both accounting and business administration programs. The engineering curricula are accredited by the Accreditation Board for Engineering and Technology. In addition, the computer science program offered in the College of Engineering and Applied Science is accredited by the Computer Science Accreditation Board, Inc. Various College of Education programs are accredited by the National Council for Accreditation of Teacher Education, including Commonwealth of Pennsylvania approval for certification programs. Programs in chemistry are approved by the American Chemical Society.

## Policy of Equality

It is the policy of Lehigh University to provide equal opportunity on the basis of merit and without discrimination because of race, color, religion, sex, age, national origin, citizenship status, handicap, or veteran status.

# Admission Guidelines

The enrollment of Lehigh University is regulated by action of the board of trustees, with a resulting limitation in the number of candidates who can be admitted each year to the several divisions of the university.

In the selective procedure necessitated by limitation on enrollment, the university, through its office of admission, takes into account a number of criteria that are believed to have some individual validity and in combination a high degree of validity in predicting success in college work.

The material that follows pertains to undergraduates. Graduate students should consult Admission to Graduate Standing, Section IV.

The admission policy of the university is designed to encourage students with varied backgrounds to consider study at Lehigh. The courses or units required for admission represent the quantitative equivalent of the usual four-year college preparatory program and include certain prescribed subjects for candidates depending upon their college and curriculum choice.

An applicant's full potential as a Lehigh student, including evidence of academic growth and the desire to learn, are special qualities that may not be reflected in mere accumulation of units. Such qualities are considered when appraising applicants.

All applicants should have completed four years of English, two to four years of history and social studies, three or four years of mathematics, and two to four years of laboratory science. Chemistry is required and physics is recommended for candidates planning studies in science or engineering.

Students planning to enter the College of Engineering and Applied Science or the College of Business and Economics, or the bachelor of science program in the College of Arts and Science, must have studied mathematics through trigonometry.

Students planning a bachelor of arts degree in the College of Arts and Science present credit upon entrance for at least two years of study of one foreign language. Further foreign language study is strongly encouraged.

One of the attractive features of the university is the ease with which a student may normally transfer from one curriculum or college to another. A student must, however, be enrolled in an undergraduate college for two semesters and be in good standing, before transferring to another college. Such transferring may necessitate a student's obtaining additional background for the new discipline on campus or elsewhere.

**Minimum subject matter requirements** (16 units)
English 4
foreign languages* 2
college preparatory mathematics** 4
electives 6

*Only in exceptional cases and for otherwise well-qualified candidates will waivers of the requirement in foreign languages be granted for admission to any one of the three undergraduate colleges.
**Waivers of the requirement in mathematics are granted to otherwise well-qualified candidates for admission who propose to major in one of the following fields offered by the College of Arts and Science: American studies, art, classics, theater, English, modern foreign languages, government, history, international relations, journalism, music, philosophy, religion studies, social relations, and urban studies.
Note: Electives should include such college preparatory subjects as languages, social studies, and sciences.

The quality of the candidate's work is more important than merely meeting minimum subject matter requirements.

The strength of preparation is judged primarily by rank or relative grade in class; by the extent to which grades are distinctly higher than the average grade; by evidence of improvement or deterioration in quality of record as the secondary school career progressed; by relative success in the subjects the student proposes to continue in college; by the degree of difficulty of courses—particularly in the senior year; and by the comments and recommendations of the principal or headmaster.

## Entrance Examinations

All candidates for admission to the freshman class are required to write entrance tests prepared and administered by the College Board.

It is the responsibility of the student, not the school attended, to request the College Board to report official scores to Lehigh.

**Scholastic Aptitude Test.** Each candidate is required to write the Scholastic Aptitude Test (SAT) to provide the university with a measure, on a national scale, of aptitude and readiness for college study. The university prefers that this test be written early in the senior year. Many students write the SAT in the junior year and ask the College Board to report the results to Lehigh. In some cases it is not necessary for students to repeat this test in the senior year.

**Achievement Tests.** Each candidate is required to write three College Board Achievement Tests. One of these must be an English test.

Candidates for a science program in the College of Arts and Science or for a program in the College of Engineering and Applied Sciences are expected to write a Mathematics (Level I or Level II) Achievement Test. Candidates for the College of Engineering and Applied Sciences are expected to write a Science (chemistry or physics) Achievement Test.

Candidates for a bachelor of arts degree from the College of Arts and Science, including five-year Arts-Engineering candidates, should write an Achievement Test (or Advanced Placement Examination) in any foreign language to be studied in college. Other candidates write tests that they may choose in consultation with their advisers. The English test and two additional Achievement Tests should be written in the senior year, unless satisfactory junior-year scores were submitted to Lehigh University.

Test information and applications may be secured from schools or the College Board at either of the following addresses (whichever is closer to the candidate's home or school): P.O. Box 592, Princeton, N.J. 08541, or 1947 Center St., Berkeley, Calif. 94704. Candidates writing tests outside the United States should direct their correspondence to the Princeton address.

Candidates should register for the tests early in the senior year and not later than one month prior to the test date (two months for candidates who will be tested in Europe, Asia, Africa, Central and South America, and Australia).

The candidate is responsible for requesting that the test scores be sent to Lehigh University—either by indicating Lehigh on the College Board application or, having failed to do this, by request to the College Board office.

## Recommendations

The office of admission secures directly from counselors, principals, or headmasters information about candidates' other qualifications. Such information relates to the candidates' health, emotional stability, intellectual motivation, social adjustment, participation in school activities, and established habits of industry and dependability.

## Interviews

Prospective freshmen and their families are highly encouraged to visit Lehigh, so that they may tour the campus and talk with an admission officer. Appointments should be made. Often it is possible to speak with faculty members and students during the visit.

The office of admission is open for interviews on weekdays from 9 to 11 A.M. and from 1:30 to 4 P.M. Tours are conducted on weekday afternoons while classes are in session. The office of admission also holds interviews on some Saturday mornings during the fall. Interviews are not held from mid-February until April 1, while applications are being reviewed.

Although a personal interview is not required of all candidates, the university reserves the right to require an interview whenever this appears desirable, and to base determination of admission in part on the report of the interviewer.

## How to Apply

Students may secure applications by writing to the Office of Admission, Alumni Memorial Building 27, Lehigh University, Bethlehem, Pa. 18015, or by telephoning (215) 758-3100. Students may also use the Common Application available from counselors in secondary schools. Applications should be filed no later than March 1. Preference is given to those received by January 1.

**Application fee.** Each undergraduate application for admission must be accompanied by an application fee. The fee is nonrefundable, whether or not the candidate matriculates at Lehigh University. It does not apply toward tuition.

**Early decision.** The university will give candidates an early favorable decision on their applications if they meet the following criteria: 1. the person is certain that Lehigh is the first choice of college; 2. preliminary credentials, including Scholastic Aptitude Test scores, show clear qualification for admission.

On this basis the committee on admission selects candidates who have submitted requests for early decision by November 1. The decision will be made by December 1. If the decision is favorable, it is assumed the candidate's academic strengths will continue throughout the senior year of high school and that all admission requirements (including College Board Tests) will be completed. On receiving a favorable decision, the candidate promptly withdraws other applications and does not apply elsewhere.

Early-decision candidates whose parents have submitted the Financial Aid Form receive notice by December 15 of the action taken on requests for financial aid.

The early-decision plan is not appropriate for all candidates. There are many candidates who are unable to make an early college choice, and they are not penalized. Candidates who do not receive favorable replies to their requests for an early decision should not feel discouraged. Only a portion of the class is selected under this plan. The committee on admission prefers to take action on most applications later in the academic year.

## Admission and Deposit

Selection of candidates for the freshman class entering in August is made between mid-February and April 1 following receipt of College Board scores and preliminary secondary school records. The university subscribes to the Candidates' Reply Date, which has been set at May 1.

When preliminary credentials are complete and the person has been offered formal admission, the university will request that the student notify the director of admission of acceptance of the offer. A deposit is also requested by Lehigh at this time to hold the place for the student in the limited enrollment. This deposit is not an additional fee but is applied toward tuition and room and board charges for the first semester. However, the deposit is forfeited in case of failure to enroll for the specified semester.

## Advanced Placement

The university offers capable students who have superior preparation an opportunity for advanced placement and/or college credit. Many secondary schools, in association with the College Board, offer college-level work. Students participating in these courses should write the Advanced Placement Tests offered by the College Board.

Students who achieve advanced placement are afforded three major advantages. First, they commence study at Lehigh at a level where they will be academically comfortable. Second, students who qualify for college credits may be graduated at an earlier time—with resulting savings in time and tuition outlay. Third, qualified students may, in the Lehigh senior year, enroll for a limited amount of work for graduate credit.

Entering freshmen who ask the College Board to send their advanced placement grades to Lehigh are considered for advanced placement. Examination grades range from a low of 1 to a high of 5.

Some departments noted below offer examinations during Freshman Orientation to students who studied college-level subjects in secondary school but did not write the advanced placement tests. Entering freshmen wishing to write an examination in any Lehigh course should notify the office of admission in writing prior to August 1. The student should specify the number and title of the course. Students who receive credit on the basis of advanced placement grades need not write Lehigh tests to confirm the credit granted.

Current practice at Lehigh is as follows:

**Art and architecture.** Three credit hours are given to those students who earn grades of 4 or 5 on the advanced placement history

of art examination. Those students who earn grades of 4 or 5 on the advanced placement studio art examination also receive three credit hours.

**Biology.** Three credit hours for Biol 21 are given to those who earn grades of 4 or 5.

**Chemistry.** Eight credit hours for Chem 21, Chem 22, and Chem 31 are granted to students who earn a grade of 5. Those students who earn a grade of 4, or who score 750 or higher on the chemistry achievement test, are granted five credit hours for Chem 21and Chem 22 and may apply to the department for a special examination that, if completed successfully, will result in an additional three credit hours for Chem 31.

**Computer Science.** Students receive three semester credit hours for CSc 11 for a grade of 3. Those students who earn grades of 4 or 5 receive four credit hours for CSc 17 instead of CSc 11.

**English.** Advanced placement and six credit hours are given for freshman English to students who earn a grade of 5. These students need not take the regular freshman English courses, but they are encouraged to elect Engl 11 and 12, seminars designed to give advanced freshmen practice in reading and writing at the college level. Students who receive a grade of 4 or who have a score of 700 or higher on the verbal section of the Scholastic Aptitude Test or the English Composition Achievement Test receive three hours of credit in freshman English; these students complete the six-hour requirement by taking an English course suggested by the department. Students whose verbal scores are between 650 and 690 and who have received a grade of 3 on the advanced placement test may apply to the department for a special examination that, if completed successfully, will result in three hours of credit and exemption from Engl 1.

**Government and Politics.** Three semester credit hours for Government I are given to students who earn grades of 4 or 5.

**History.** Students who receive a grade of 3 on the American History or European History Test receive advanced placement but not credit. Those who earn grades of 4 or 5 on the American History Test receive six semester hours of credit; those who earn grades of 4 or 5 on the European History Test receive three semester hours of credit. A special course, Hist 51, is available to qualified students.

**Latin.** Students receive three semester hours of credit for a grade of 4 or 5 in the Vergil examination; those who successfully write examinations in more than one area (e.g. Vergil and lyric poetry) receive six hours of credit.

**Mathematics.** Four semester hours of credit for Math 21, Analytic Geometry and Calculus I, are granted to those who earn grades of 3 or higher on the Calculus AB examination. To those who earn grades of 3 or higher on the Calculus BC examination, eight hours of credit are granted for Math 21and Math 22, Analytic Geometry and Calculus I and II.

**Modern foreign languages.** (French, German, Hebrew, Russian, Spanish). Students receive three semester hours of credit for grades of 4, and six hours of credit for grades of 5 on the advanced placement tests. Those who write the achievement tests and score 750 to 800 receive three hours of credit. The maximum number of credits given is six.

**Music.** Three semester hours of credit are given to those students who earn a grade of 3 or higher on the advanced placement test in Music: Listening/Literature of Music: Theory.

**Physics.** Four hours of credit are given for Physics 11, Introductory Physics I, for a grade of 5 on the Physics B examination or a grade of 4 on the mechanics section of the Physics C examination. If a student receives credit for Physics 11, four hours of credit will be given for Physics 21, Introductory Physics II, for a grade of 4 on the electricity and magnetism section of the Physics C examination. If a student wishes to be considered for credit for Physics 12 or 22, Introductory Physics Laboratory I and II, he or she should see the chairperson of the physics department with evidence of laboratory experience. A test is offered during freshman orientation.

**International Baccalaureate.** Students who earn the international baccalaureate are granted credit in higher-level subjects in which they earn scores of 5 or higher.

## Transfer Students

Each January and August, students who have attended other colleges and universities are admitted with advanced standing. Candidates for transfer admission must meet the high school subject matter requirements prescribed for entering freshmen. Entrance examinations are not required. The quality of the college record and the number of spaces available in the program the student wishes to study are the major considerations of the Committee on Admission in reviewing transfer applications.

A candidate who has been dropped from another college for disciplinary reasons or for poor scholarship or who is not in good standing at another college is not eligible for admission.

A candidate who has attended more than one junior college, college, or university (including summer and special sessions) must present an official transcript from each institution. Failure to submit a complete report of academic experience will result in cancellation of admission or registration.

Those students wishing to enter in the spring semester should apply not later than November 1; fall semester applicants should apply no later than April 1.

Students may obtain applications by writing to the Transfer Section, Office of Admission, Alumni Memorial Building 27, Lehigh University, Bethlehem, Pa. 18015, or by telephoning (215) 758-3100.

When the receipt of the application is acknowledged by the office of admission, the student is advised of the time when transcripts and other documents should be submitted. Decisions on applications are reached soon after the middle of the semester preceding the one the student wishes to enter the university.

# Estimate of Expense for Undergraduates

The operating expense of Lehigh University is supported principally by three areas of income: tuition and fees; endowment earnings, and gifts and grants. The university is conscious that educational costs are significant and it strives to maintain a program of high quality instruction while recognizing that there are limitations on what families can afford to pay. Costs will vary somewhat from student to student depending upon the various options chosen.

## Tuition, Room, and Board

There are three major plans that cover the major expense associated with university attendance. These are as follows:

**The tuition plan.** The university provides comprehensive academic and student services under its tuition plan. The tuition sum is inclusive of most athletic events, basic treatments in the Health Center, libraries, and laboratory services. An additional $250 fee is charged to sophomore, junior, and senior students enrolled in the College of Engineering and Applied Science or majoring in natural science. The full-time tuition rate is charged to students enrolled in twelve or more credit hours per semester. For students enrolled in less than twelve credit hours, tuition is charged on a per-credit-hour basis.

**The residence halls plan.** A variety of living arrangements are available. The university provides housing for 2,200 students on or near the campus in a wide selection of housing facilities. The housing arrangements are grouped within three basic categories, with rates associated with the category level. In order to guarantee a space within a residence halls unit, a $200 deposit is required for each semester. This deposit is credited toward the room charge for the respective semester. For entering freshmen, the deposit is not refundable if they make other plans. For returning students, the fee is refundable based upon a published schedule.

**The board plan.** Five board plans are available. The basic 21-Meal Plan is required for all freshman residents. Upperclass students living in residence halls have the option of participating in the Any-10-Meal Plan. Students residing in fraternities, campus apartments, or any off-campus facilities are eligible to participate in any of the plans. There is a special plan required for sororities located on the South Mountain campus.

## Tuition and Fees

All charges and fees are due two weeks prior to the start of classes each semester. On a per-term basis, the expenses are charged at

one-half the per-year charge. Accounts not settled by the due date are subject to a late-payment fee. All figures given are for the academic year (two semesters).

| | |
|---|---|
| **Tuition,** 1989-90 | $13,550 |
| **Residence Halls** | |
| Category I (Dravo, Drinker, Richards, and McClintic-Marshall houses) | $2,240 |
| Category II (Centennial Houses I and II, Packer House, Warren Square and Hillside) | $2,540 |
| Category III (Trembley Park, Brodhead House, Gipson College, Hartman College, More College, and Taylor College) | $2,720 |
| **Board** | |
| Plan A (21 meals per week, required of all freshmen) | $1,830 |
| Plan B (any 10 meals selected throughout the week) | $1,600 |
| Plan C (5 meals, lunch Monday through Friday) | $610 |
| Plan D (5 meals, dinner Monday through Friday) | $990 |
| Plan E (sorority plan of 5 breakfasts and 5 lunches Monday through Friday) | $1,120 |
| Plan F (sorority plan of any 10 meals selected throughout the week) | $1,300 |

Based upon the above charges, most freshmen are normally billed the tuition rate along with the Category I room fee and the Plan A food plan. The total cost for the three areas would be $17,620 for the 1989-90 academic year.

| **Other Fees** (applied to prevailing circumstances) | |
|---|---|
| Per credit charge for credit and audit | 565 |
| Engineering and Science Fee (for specified students) | 250 |
| Application fee (for undergraduate admission consideration) | 40 |
| Late preregistration | 50 |
| Late registration | 50 |
| Late application for degree | 25 |
| Examination make-up (after first scheduled make-up) | 10 |
| Late payment (after announced date) | 50 |
| Returned check fine | 20 |
| Key penalty, residence halls (non-return) | 10 |
| Key duplicate, residence halls | 5 |
| Lost room key/lock change, residence halls | 25 |
| Identification card (replacement) | 10 |

The university reserves the right at any time to amend or add charges and fees, as appropriate, to meet current requirements. Fees applicable to the 1990-91 academic year will be announced no later than January, 1990.

# Other Expenses

A student should plan to meet various other expenses. These expenses include the purchase of books and supplies from the Lehigh University Bookstore located in Maginnes Hall. Necessary purchases supporting one's academic program should average approximately $500 per year. The bookstore carries basic goods for students' needs. A student should also plan an allowance to handle personal and travel expenses.

# Plan of Payments

An itemized statement of charges is mailed from the bursar's office approximately six weeks prior to the start of each semester. Payment is expected in full by the specified due date. Payment plans are available for those desiring extended payment arrangements.

Persons desiring a payment plan can elect participation in either the Mellon Bank Edu-Check Plan, the Richard C. Knight Tuition Plan, or The Tuition Plan. The university also offers a plan under which enrolled undergraduate students can pre-pay more than one year of tuition at current rates. Complete information is available from the bursar's office. Those persons desiring to use one of the plans must complete the necessary details no later than two weeks prior to the due date for payment.

Students attending the university under a provision with a state board of assistance or with financial aid from other outside agencies must provide complete information to the bursar's office if assistance is to be recognized on the semester statement.

# Refunds of Charges

**Tuition refunds.** A student in good standing who formally withdraws (within the first eight weeks of a semester) or reduces his or her course enrollment below twelve credit hours will be eligible for a tuition refund. The refund schedule for student withdrawals and course adjustments is as follows:

| | |
|---|---|
| prior to the start of the semester | 100% |
| during first calendar week | 80% |
| during second calendar week | 70% |
| during third calendar week | 60% |
| during fourth calendar week | 50% |
| during fifth calendar week | 40% |
| during sixth calendar week | 30% |
| during seventh calendar week | 20% |
| during eighth calendar week | 10% |

Full-tuition refunds will be allowed for registration cancellations, or reductions in rosters, only in those instances when a notice is presented in writing to the registrar prior to the start of a semester. If the student has financial aid, he or she should consult the financial aid office as reductions in tuition charges may also result in a reduction of financial aid. Cancellation and reduction notifications received after the start of a semester will be recognized based upon the calendar week in which it is received by the registrar.

In the event of the death of a student, tuition will be refunded in proportion to the semester remaining.

**Tuition Credit/Suspension.** A student who is suspended from the university for disciplinary reasons will be eligible for a tuition credit toward the semester immediately following the period of suspension. The amount credited will be based on the following schedule and calculated on the tuition rate in effect during the period of suspension:

| | |
|---|---|
| prior to the start of semester | 100% |
| during first calendar week | 80% |
| during second calendar week | 70% |
| during third calendar week | 60% |
| during fourth calendar week | 50% |
| during fifth calendar week | 40% |
| during sixth calendar week | 30% |
| during seventh calendar week | 20% |
| during eighth calendar week | 10% |

The date that will be applied to the tuition credit will be the date of the incident that resulted in the suspension. Under no circumstances will a tuition *refund* be provided to students who are suspended for disciplinary reasons.

**Summer Sessions.** The university does not issue bills for summer registration. Students are expected to make payment at the time of registration. If you require a bill for any reason, a special request should be submitted to the Bursar prior to May 1. Registration will not be permitted until all charges are paid. Students in good standing who formally withdraw or reduce their course enrollment within the first four weeks of a summer term will be eligible for a tuition refund. The refund schedule for student withdrawals and course adjustments is as follows:

| | |
|---|---|
| prior to start of summer session | 100% |
| during first calendar week of summer term | 80% |
| during second calendar week | 60% |
| during third calendar week | 40% |
| during fourth calendar week | 20% |

Full tuition refunds will be allowed for registration cancellations or reductions in rosters only in those instances when a notice is

presented in writing to the Registrar prior to the start of a summer term. Cancellation and reduction notifications received after the start of a summer term will be recognized based upon the calendar week in which it is received by the Registrar.

*Because of the short time involved, no refunds for tuition charged in the one-week workshops will be made after the first day of class.*

In the event of the death of a student, tuition will be refunded in proportion to the fraction of the summer term remaining at the time of the death.

**Residence hall refunds.** Residence hall rooms are rented on an annual basis only. An advance deposit of $200 for each semester is required to hold a room for the respective semester. This deposit is nonrefundable to entering freshmen and either full or partially refundable to upperclass students based upon specific criteria and a published refund schedule. Refunds are made in full in the event a student does not register because of illness, injury, or death, is dropped from the university due to academic reasons, attends a university approved study abroad or co-op program, or graduates. Partial refunds during the year are possible in the event of a voluntary withdrawal only with the provision that the lease can be transferred to another student for whom no other university accommodations exist. Prorated refunds are based upon the date the room keys are returned to the Office of Residential Services. Any student suspended or expelled from the university will not be granted any room refund.

**Refunds for board plans.** Board refunds are made in full in the event a student does not register because of illness, injury, death, is dropped from the university due to academic reasons, attends university approved study abroad or co-op programs, or graduates. Meal Plan refunds after the start of the semester are prorated based on the number of unused days remaining in the board plan at the time the plan is discontinued and the Bursar's Office is notified in writing. Prorated refunds may be granted based on voluntary withdrawals or separation from the university due to illness, injury, or death.

Meal plans may be changed within the requirements of the living area up to the 10th day of class of each semester. Changes outside of the required meal plan or after the 10th day of class for reasons such as medical condition, etc., must receive approval from Auxiliary Services. If such changes are approved, cost adjustments will be processed on a prorata basis as of the date of the last meal purchase.

Any student suspended or expelled from the university will not be granted a board plan refund. A student suspended may receive a prorated meal plan credit toward the semester immediately following the period of suspension.

**Adjustments to financial aid.** The office of financial aid is responsible for determining the appropriate redistribution of charges and refunds when students are in receipt of financial assistance. These decisions are made on the basis of university, federal, and state agency regulations. Adjustment procedures, where financial assistance (including GSL and PLUS loans) is concerned, are on file in the office of financial aid.

# Financial Aid

The university offers financial assistance to U.S. citizens and permanent residents, based on financial need and academic promise. The competition for scholarship funds is keen; therefore it is important to read and understand the application procedures and to file the correct forms.

Lehigh expects that all families of its students will make every effort to pay tuition and other educational expenses. The aid program is focused to measure the dollar difference between the cost of attendance and the amount of money the family can contribute towards that cost. This difference is called "financial need." Most financial assistance is awarded on the basis of this calculated need.

Approximately 35 percent of the 1989 freshman class will enroll with university scholarships ranging, according to need, from $100 to $15,500. An additional 15 percent will enroll with aid from sources other than Lehigh, including state and federal grants, ROTC scholarships, aid from private sources, and educational loans.

There are four forms of financial aid available at Lehigh: scholarships, grants, loans, and employment. *Scholarships* are based on academic achievement and need not be repaid; most have financial need as a criterion for eligibility. *Grants* are based on financial need and satisfactory academic progress; they do not require repayment. *Loans* are borrowed from a variety of resources and are repayable at low interest rates after the student ceases to be enrolled. *Employment* provides money for books and personal expenses, through wages paid bi-weekly.

Additional sources of aid are state agencies, employers, and various clubs, churches, religious and fraternal organizations, and foundations. High school guidance counselors may be able to provide information on local aid programs. Students are required to apply for all possible kinds of outside financial assistance, particularly the Pell Grant and state grant programs, which are important resources. Students are expected to take maximum advantage of outside sources to enable Lehigh to spread funds farther and to limit student borrowing.

## Application Procedures

Families of freshmen desiring financial aid file a Financial Aid Form (FAF) with the College Scholarship Service (CSS) between January 1 and February 10 of the student's senior year in high school. Forms are normally available in guidance offices in December.

The Financial Aid Form is a two-sided document which must be completed in its entirety. Pennsylvania residents are advised to use their Pennsylvania Higher Education Assistance Agency (PHEAA) application for requesting Pell Grant consideration when applying for the state grant.

All applicants should request that the College Scholarship Service send their analysis of the application to Lehigh. The Lehigh code number is 2365. Applicants should also have CSS send the information to both the Pell Grant program and the state scholarship agency (where appropriate). If the student is granted aid from Lehigh for 1989-90, a signed copy of the parents' and student's 1988 IRS Form 1040, with schedules, must accompany the acceptance. If possible, the tax returns should be sent as soon as prepared to help with the review of the FAF. Aid awards are not final until the FAF and Form 1040 are cross-checked. Award adjustments are made where differences in income and assets exist.

Additional forms are required of students whose parents are divorced or separated. The student applicant and the parent with whom the student resides (i.e., the custodial parent or "at home" parent), complete the FAF. If that parent is remarried, the stepparent's information must also be included. The other (non-custodial) parent is asked to complete the Divorced/Separated Parent's Statement. Lehigh requires this statement, and will mail it to the applicant soon after receiving the FAF, although it may be requested in advance.

Parents who are self-employed, or who own an income-producing farm, must file a Business or Farm Supplement, available from the office of financial aid.

**Renewal of aid.** It is necessary to reapply for financial aid for each year of study. Applications and filing instructions are available in mid-February in the office of financial aid, or as otherwise posted.

Upperclassmen file the FAF with the CSS by April 1. A Lehigh application form must also be completed and returned to the university's office of financial aid by April 1, accompanied by a signed copy of both the parents' and the applicant's 1989 IRS 1040 (with all schedules filed), as well as those additional forms required for special circumstances, such as the Divorced/Separated Parents Statement. Upperclass applications are not reviewed until the FAF, Lehigh application, and income tax forms are received.

In addition, to receive any type of aid a student must make satisfactory academic progress each year. University policy on satisfactory academic progress is available in the office of financial aid. Recipients of Lehigh grants and scholarships are expected to achieve at least the level of the all-university average (2.6). Students on academic or disciplinary probation are ineligible for university scholarship aid during the period of their probation. Students not maintaining satisfactory progress, as defined by Lehigh, are ineligible for all forms of federal aid, including loans and employment. Appeals based on extenuating circumstances are submitted to the committee on undergraduate financial aid.

Eligibility for financial aid is determined by calculating the amount a family can contribute to the cost of attendance based on income, assets, family size, number in college, and other factors. The

expected contribution is then subtracted from the cost of attendance to yield "financial need."

This year, under federal methods used to determine financial need, the greater of $700 or 70 percent of the student's net earnings will be used as part of the family contribution for freshmen, and the greater of $900 or 70 percent for upperclassmen.

In general, a student might be expected to have some need when the family's annual income and number of tax dependents (usually children) are as follows:

| | |
|---|---|
| with one child at home | $45,000 |
| with two children at home | $50,000 |
| with three children at home | $55,000 |
| with four children at home | $60,000 |

The figures above are for income before taxes and deductions, allowing for normal savings and home equity, with one child attending college. When more than one child is in college, the likelihood of financial aid is increased. Families with incomes as high as $75,000 are able to establish financial need if, for example, they have three children, all enrolled in independent universities like Lehigh.

## Sources of University Aid

Several forms of university-funded aid, based on need and merit, are available.

**Trustee scholarships.** Funds are budgeted from general income to provide awards covering the tuition charges in whole or in part.

**Sponsored scholarships.** Individuals, foundations, and corporations provide these funds through annual contributions to the university. Lehigh has 140 such sponsors, with awards ranging from $300 to full tuition.

**Endowed scholarships.** Income from invested gifts to the university makes these scholarships possible. The university has 279 such funds, half of which are for general, unrestricted use. Most of the others are restricted by curriculum or geographic criteria.
*Geographic Restrictions:* Pennsylvania, New Jersey, Delaware, Maryland, Ohio, Massachusetts, Virginia, Colorado, Texas, Georgia, North Carolina, Tennessee, Missouri, Kansas, Richmond, VA, Kansas City, MO, Jackson County, MO, Johnson County, KS, Hammonton, NJ, Allentown, PA, York County, PA, New York City, NY, Baltimore, MD, Western, PA.
*College of Arts and Sciences:* Geology and Geological Science, Premedical Science, Journalism and Science Writing.
*College of Business and Economics:* Accounting, marketing, economics.
*College of Engineering and Applied Sciences:* Applied mathematics, civil engineering, chemical engineering and chemistry, computer science, electrical engineering, industrial engineering, mechanical engineering, metallurgy, physics and engineering physics.
*Miscellaneous:* Musicians (brass instruments); Gryphons; employees of U.S. Steel, Milton Roy Sheen, and Alperin Co.; members of certain fraternities.

**Merit scholarships.** Lehigh is a collegiate sponsor of the National Merit Scholarship program. Scholarships ranging from $500 to $2,000 per year may be awarded to Merit finalists selecting Lehigh as their first-choice college, and who are not also receiving another form of National Merit scholarship.

**Athletic awards.** Alumni Student Grants are awarded on the basis of financial need and exceptional athletic talent as evaluated by the department of intercollegiate athletics. Grants are supported by annual alumni contributions. ASG recipients refile the Financial Aid Form annually to determine the amount of their grant eligibility. In addition, there are a number of restricted endowed funds for use with intercollegiate sports participants.

**University tuition loans.** Parental endorsement is required on the promissory note. Repayment begins three months after graduation or withdrawal from the university, until the loan principal and interest are repaid. The minimum monthly repayment rate is $50 plus interest, which is 9 percent per annum, accruing only during the repayment period. Deferment is available for students who return to school at least half-time. Other deferments are available for students who are in the military, VISTA, or Peace Corps, up to a maximum of three years; or those who are experiencing undue hardship.

Lehigh maintains these loan funds to be used to supplement or replace other types of educational loans. The guiding factor in awarding university loans is that the combination of loans (federal, state, and institutional) shall not exceed one-half the cumulative tuition to be paid through the award period. If, for example, the total tuition over three years amounted to $36,000, a university loan would not be offered if total borrowing exceeded $18,000.

**Loan-cancellation awards.** This unique Lehigh award is used as an aid alternative for students whose academic average is not sufficiently competitive for scholarship consideration. L-C begins as a loan, with the same terms as Lehigh loans. The specified average must be earned during the term of this award for the loan to be cancelled and replaced by a scholarship. If not cancelled, the loan is repayable according to the terms for university tuition loans.

## Availability of jobs

Students may receive an employment allocation as part of their aid package. Pay rates range from the federal minimum wage to $4.45 per hour. Jobs are available throughout the university, and are funded through federal and university sources.

Aid recipients who do not receive a job as part of their aid package probably cannot earn more than $100 in outside wages without becoming "over-awarded," meaning that the sum of all resources exceeds computed need. "Over-award" status can lead to a reduction in an aid package.

## Aid from the government

Students who apply for university aid are automatically considered for three programs sponsored by the U.S. Department of Education. Each year the university applies for funding for these programs. The number of awards is determined by the amount of money granted to Lehigh.

**Supplemental Educational Opportunity Grants,** ranging from $100 to $4,000, aid students of exceptional financial need.

**Carl Perkins (National Direct Student) Loans** enable the University to lend up to $4,500 for the first two years of undergraduate study, and $9,000 for all years of undergraduate study. Repayment begins six or nine months after graduation or withdrawal, and can be extended.

During the repayment period, 5 percent interest is charged on the unpaid balance. Deferments are available to students who return to school at least half-time, including professional internships. Other deferments are available for cases of undue hardship, and for those students active in the military, VISTA, or Peace Corps. Cancellation of all or some of the loan is available to students teaching in public schools appearing in the Federal Register, and to those students who suffer total disability.

The **College Work-Study** program subsidizes the wages that students earn in campus jobs.

**Pell Grant.** Students apply directly to the federal government for a Pell Grant by using the FAF, the PHEAA/state grant application or the Federal Student Aid Application. Pell grants range from $200 to $2,300.

**State grants.** Several states offer financial assistance that can be used in Pennsylvania. High school guidance personnel can provide information regarding eligibility and application procedures.

Pennsylvania residents may be eligible for grants ranging up to $2,100. Lehigh students also have received grants from Connecticut, Delaware, Massachusetts, Ohio, Rhode Island, West Virginia, Vermont and Maryland.

**ROTC scholarships.** The departments of military science and aerospace studies award scholarships that provide payment for tuition, books, and other fees as well as $100 per month. Recipients incur an obligation to serve on active duty as commissioned officers in the Army or Air Force. The Air Force has a second category of ROTC scholarships that limits payment towards tuition to $7,500.

**Robert T. Stafford Loans** (Formerly Guaranteed Student Loans). Applications for the Robert T. Stafford Loans are available from lending institutions. Students applying through PHEAA (Pennsylvania Higher Education Assistance Agency) return their completed applications to the lending institution. Students applying through out-of-state lending institutions return their applications to the Lehigh Office of Financial Aid. Stafford Loan eligibility is determined through the results of the Financial Aid Form. Students may borrow $2,625, less a loan-origination fee of 5 percent, for their

freshman and sophomore years of study, and $4,000 per year for their remaining years of undergraduate study.

Stafford Loan recipients must maintain good academic standing and make satisfactory progress toward a degree. Stafford Loans are repayable in monthly installments commencing six months after the borrower ceases to be enrolled at least half-time. Interest is currently eight percent per annum, for new borrowers, and is federally subsidized until the repayment period begins. Interest increases to 10 percent after the fourth year in repayment.

Deferment is available any time the borrower returns to at least half-time study in an approved program. A single deferment, for a period of not more than two years, is also provided for students who are unable to find full-time employment. In addition, borrowers do not have to make payment for up to three years while serving in the armed forces, Peace Corps, or in full-time volunteer programs conducted by ACTION. Several new deferments are now available for: the unemployed; women on maternity leave, teachers, single parents with disabled children, and active-duty members in the National Oceanic and Atmospheric Administration(NOAA).

The university recommends the Stafford Loan as part of most aid packages, reserving Perkins Loans and University Tuition Loans as a supplement to the Stafford Loan where work-study funds are not available.

**Non-Subsidized Guaranteed Student Loans.** For students ineligible for interest-subsidized GSLs, the state of Pennsylvania offers non-subsidized GSLs. The terms and conditions of the non-subsidized GSL are similar to those of the subsidized GSL except that the interest on a non-subsidized GSL must be paid in quarterly installments to the lender while the student (borrower) is attending school. Loan applications can be obtained at local lending institutions. Needs analysis forms (the Financial Aid Form) can be obtained in the Office of Financial Aid.

**Supplemental Loans for Students / Loans for Parents.** All students, except dependent undergraduates, are eligible for the Supplemental Loan Program. The loan limit is $4,000, with the cumulative limit at $20,000. The same annual and aggregate limits apply to the program of **Loans for Parents.** These loans can be used to cover the expected family contribution required in determining need in other financial-aid programs. A variable interest rate is established for both of these programs. Interest will be the one-year Treasury Bill rate, plus 3.75 percent, with a maximum of 12 percent.

**PHEAA-HELP Alternative Loans.** All students attending Pennsylvania institutions are eligible to borrow through the Pennsylvania Higher Education Assistance Agency (PHEAA). The Higher Education Loan Program (HELP) allows students to borrow up to $10,000 a year, depending on a credit-worthiness evaluation done by PHEAA. The variable interest rate has a limit of 12 percent. The current rate is 9.5 percent. Specific information and application forms are available from PHEAA and from educational institutions in Pennsylvania.

## Checklist for Financial Aid

1. *Returning students and transfer applicants only*: Submit the Lehigh application for undergraduate financial aid. Be sure to complete all questions.

2. The FAF should be completed by parents and applicants and submitted to the CSS, listing Lehigh University, CSS code 2365, in item 91, and answering "yes" to questions 99 and 100 to ensure both university and Pell Grant consideration. Forms are available from high school guidance counselors or the Office of Financial Aid during December.

3. Submit a state grant application, particularly if you are a resident of Pennsylvania, Ohio, Massachusetts, Connecticut, Rhode Island, Maryland, Delaware, Vermont, or West Virginia.

4. Submit signed copies of the 1989 IRS form 1040, all pages and schedules, filed by student and parents. Income statements for those who will not file a 1040 are available from the Office of Financial Aid.

5. Check to be sure your social security number is correctly listed on all forms. If you do not have a number, apply for one and notify Lehigh as soon as it is received.

6. For your records, photocopy the completed FAF and any other applications you submit.

7. *Transfers only*: Be sure to have your previous college(s) complete and forward the Financial Aid Transcript.

# Campus life

Approximately 85 percent of all undergraduate men and women live on campus. Campus living facilities include residence halls, apartments, suites in a multi-story building, or residence in fraternity houses or sorority units. Physical facilities are also described in Section VI.

## Residence Halls

The offices of Residential Life and Residential Services at Lehigh University are committed to providing quality housing and educational services to its resident students. Lehigh firmly believes that living in a residence hall allows students to become members of a special community, offering the opportunity to live with and learn from a diverse group of people. Efforts are made to integrate academic and out-of-the-class learning in order to enable students to develop a balanced and realistic approach to life after they leave the university.

When a candidate accepts an offer of admission to the freshman class, the candidate is sent a Room and Board Application-Contract. Those desiring accommodation in the residence halls must return this application-contract promptly. Priority of assignment is based on date of receipt of this application. A nonrefundable advance deposit of $200 must accompany the application and will be credited to the fall semester room charges. Normally, freshmen are informed of their room assignment and other information in early August by the Office of Residential Services.

Currently, the demand for upperclass campus housing exceeds the supply by approximately 10 percent. For the duration of this imbalance, the University Forum has approved the use of a lottery to provide for fair and equitable distribution of available housing among upperclass students. The lottery is scheduled early in the spring semester. Those students who are guaranteed housing pay a $200 deposit to hold the space for the following academic year.

To help facilitate and maximize a student's residence experience, approximately ninety staff members of the office of residence life live in the residence halls. On every hall there is a student staff member, a Gryphon, who provides assistance in personal and academic matters, refers students to other offices where appropriate, helps mediate conflicts, and develops educational, social, and recreational programs. In addition to the student staff, graduate hall directors and full-time professional staff members live in the residence halls thus providing additional resources for students.

In every residence hall there are also House Councils that are part of the larger Residence Hall Council. Participation in the Residence Hall Council provides a chance to develop leadership, programming, human relations, and budgeting skills. It is a vital and active organization, whose prime focus is to help fund residence hall programs, to assess students' opinions on issues affecting them, and to develop many service-oriented programs to aid resident students in their stay on campus.

More than half of Lehigh undergraduates live in university residence halls. The university has ten principal residence halls for undergraduate men and women. Most rooms are designed for two students, but a limited number of single, triple, or suite arrangements, and apartment units, are available. Residence halls offer a wide variety of special live-in programs including: Taylor residential college, a German House, an International House, traditional-style living (in buildings with corridors), and suite/apartment-style living.

## Fraternities and Sororities

The university has one of the strongest Greek systems in the nation. The continued strength of this system is due in part to the efforts of the Interfraternity Council, Panhellenic Council, the Greek Alumni Council, the office of the dean of students, and the residential services office to improve the quality of fraternity and sorority life through pledging, leadership, social, educational, housing, and financial management programs.

Greek life is an attractive alternative among the residence options at Lehigh. Each fraternity or sorority is a relatively small, close-knit community. These groups determine their own goals, manage their own houses and business affairs, conduct their own social, philanthropic, and athletic activities, plan their own meals, and select their own members. Because they are largely self-governing, these organizations offer numerous opportunities for student involvement and leadership.

The thirty-two fraternities and eight sororities form a larger Greek community comprising approximately 45 percent of the undergraduate population at Lehigh. Through the Interfraternity Council (I.F.C.) and Panhellenic, they determine policies and organize social, philanthropic, and educational activities for the Greek community as a whole. In cooperation with the Forum, Student Activities Council, Residence Halls Council, and the office of the dean of students, the I.F.C. and Panhel also help to develop programs and policies for the wider university community.

There are eight sorority chapters at Lehigh. They are housed in the Centennial I complex on the South Mountain Campus and in Saucon Village. The sororities are Alpha Chi Omega, Alpha Gamma Delta, Alpha Omicron Pi, Alpha Phi, Delta Gamma, Delta Zeta, Gamma Phi Beta, Kappa Alpha Theta.

Twenty-seven of the fraternities are located on campus in Sayre Park. The remainder are located near the campus. The fraternities are Alpha Chi Rho, Alpha Epsilon Pi, Alpha Sigma Phi, Alpha Tau Omega, Beta Theta Pi, Chi Phi, Chi Psi, Delta Chi, Delta Phi, Delta Sigma Phi, Delta Tau Delta, Delta Upsilon, Kappa Alpha, Kappa Sigma, Lambda Chi Alpha, Phi Delta Theta, Phi Gamma Delta, Phi Kappa Theta, Phi Sigma Kappa, Pi Kappa Alpha, Pi Lambda Phi, Psi Upsilon, Sigma Chi, Sigma Alpha Mu, Sigma Nu, Sigma Phi, Sigma Phi Epsilon, Tau Epsilon Phi, Theta Chi, Theta Delta Chi, Theta Xi, and Zeta Psi.

## The University Forum

The Lehigh University Forum is a unique deliberative body whose purpose is to promote the welfare of the university and attainment of a true sense of community by bringing into discourse students, faculty, and administration.

Its membership includes elected representatives of the student body and of the faculty, and members of the administration (including the president, provost, vice president for student affairs and dean of students).

Four Forum representatives—two students and two faculty members—attend meetings of the board of trustees. Assured of access to the information upon which administrative decisions are based and free to inquire into any aspect of university operations, the Forum affords faculty and students a voice in university affairs equaled at few institutions.

The Forum has been particularly effective in the following areas: extracurricular activities and social life; planning that involves special educational opportunities; the academic environment; long-range planning and budget; and appointments at the level of dean or higher.

Three Forum committees—academic environment, administration, and campus life, are each jointly headed by a faculty member and a student. Numerous subcommittees work on specific issues,allowing Forum members either to work on a broad range of topics or to concentrate on particular aspects of university life they find most important. Many non-Forum students also work actively on subcommittees, and in some cases serve as chairpersons. This participation provides valuable background and experience for later candidacy to the Forum or other elective positions.

The Forum also appoints student members to certain standing committees of the faculty and certain ad-hoc university committees when invited.

All meetings of the Forum are open to the university community, with the right to address the Forum provided to any person desiring to do so. The Forum office is located in Packer Hall, the university center, and students are invited to come in to discuss any aspect of university government.

## Honorary and Course Societies

There are at least fifteen honorary and course societies. The three best-known are:

**Phi Beta Kappa.** The oldest national scholastic honorary society (founded December 7, 1776, at the College of William and Mary) recognizes high academic achievement as well as a breadth of interest in the liberal arts and the natural and social sciences. Admission to its ranks is also held to indicate potentialities of future distinction. The Lehigh chapter was chartered in 1887 as Beta of Pennsylvania.

**Beta Gamma Sigma.** Election to membership in Beta Gamma Sigma is the highest scholastic honor that a student in business administration can achieve. Beta Gamma Sigma is the only national honorary scholarship society in the field of business administration recognized by the American Assembly of Collegiate Schools of Business.

**Tau Beta Pi.** Tau Beta Pi recognizes high achievement in all engineering curricula. The national Tau Beta Pi was founded at Lehigh in 1885. A bronze marker in front of Williams Hall commemorates this event.

Among course societies are the following: Alpha Pi Mu, for those in industrial engineering; Beta Alpha Psi, accounting; Chi Epsilon, civil engineering; Eta Kappa Nu, electrical engineering; Lambda Mu Sigma, marketing; Omicron Delta Kappa, leadership; Phi Alpha Theta, history; Phi Eta Sigma, freshman scholastic excellence; Pi Tau Sigma, mechanical engineering; Psi Chi, psychology; Sigma Tau Delta, English; and Sigma Xi, research.

## Religious Activities

The religious program is under the general supervision of the university chaplain. The chaplain also provides for Protestant chapel services, broadly based and ecumenical in form, varying from the traditional to the informal and innovative. Some services feature the university choir; others, folk music. Roman Catholic masses are arranged by the Newman Association Center chaplain. Packer Memorial Church is the center for campus worship services. Given in honor of Lehigh's founder, Asa Packer, the chapel will celebrate its centennial during 1987.

Protestant and Roman Catholic service schedules are announced at the beginning of the year. Jewish services are available nearby in the community. Attendance at all religious services is voluntary. The university is nondenominational.

The university chaplain works with representatives from campus religious groups of all faiths and jointly sponsors a variety of programs together with those organizations. The chaplain's office has sponsored, in addition, luncheon programs and a film series, both with discussions; talks by religious leaders (including recently Bishop Desmond Tutu of South Africa and Elie Wiesel, author and Holocaust survivor) and faculty members; and multi-media presentations. The programs are open to all students.

The Newman Association offers a program for Catholic students under the guidance of a priest. The association has its own building on campus.

The Hillel Foundation supports a program for Jewish students including a Hillel House as a focus of activity. Activities are guided by a full-time Hillel advisor. A limited kosher meal plan is available at the Hillel House.

Protestant students have a variety of fellowship programs available to them, both on campus through the Lehigh Christian Fellowship, the Navigators and other groups, and off campus with the various churches nearby.

## Student Organizations

Lehigh offers a wide field of extracurricular activities and student organizations. There is a campus radio station, a twice-weekly student-run newspaper, a dramatic club, musical organizations, and many other opportunities for participation. Course societies promote intellectual interest in various fields of study and develop professional spirit among students.

Interest and hobby groups include art, ballet, band, chess, camera, computer, languages, rugby, sailing, skiing, boxing, judo, model railroading, political clubs, fencing, and waterpolo. These are described in the *Lehigh Handbook*, which is distributed to all students.

Many students also are elected to honorary societies and others join course societies.

## Lehigh University Theatre

The department of theatre sponsors play productions that provide opportunities for onstage or backstage participation. In conjunction with the Mustard and Cheese Dramatics Society, founded in 1884, four mainstage productions are undertaken annually in the Wilbur Drama Workshop, ranging in style from the classics to the *avant-garde*.

Recent productions have included "*The Tempest,*" "*Tartuffe,*" "*The Roar of the Greasepaint—The Smell of the Crowd,*" "*The House of Blue Leaves,*" "*Oedipus Rex,*" "*Fifth of July,*" "*Hedda Gabler,*" "*A Midsummer Night's Dream,*" and "*Waiting for Godot.*" Students act, work behind the scenes and sometimes design and direct with full theatre faculty participation. For the general student population, participation in a production is an extracurricular activity combining artistic and social interaction.

Independent student work is promoted and encouraged through the Lab Theatre program. Located in Coppee Hall, the Lab Theatre is dedicated to student exploration of the relationship between performers and text. "*The Carpenters,*" "*The Maids,*" "*Sister Mary Ignatius Explains It All For You,*" "*The Zoo Story,*" "*Miss Julie,*" "*Tintypes,*" "*Doctor Faustus,*" and "*The Mousetrap,*" are recent student-directed Lab Theatre productions.

Our artist in residence program brings actors, directors, playwrights and designers to campus annually. These professionals interact with our students and faculty on mainstage productions and in classes.

The department sponsors touring professional productions, adding to the cultural life of the campus. These productions have included performances by the National Theatre of the Deaf and The San Francisco Mime Troupe as well as residencies by the Pennsylvania Dance Theatre and Touchstone Theatre.

## Musical Organizations

The university sponsors both a variety of student musical organizations that give performances on and off campus and a professional concert series, Music at Lehigh, that brings visiting artists to the campus. The choruses, bands, orchestra, and ensembles are conducted by members of the faculty and managed by elected student leaders.

Christmas Vespers and Spring Vespers are traditional choral performances. The university choir has toured Canada, Puerto Rico, the Virgin Islands, Washington, D.C., and throughout Pennsylvania.

The Choral Union, formed in 1985, performs major works with orchestra. It is open to all students, faculty, and staff as well as members of the community.

The Wind Ensemble plays a winter concert and a pops concert on campus during the spring and takes an annual tour to various locales (Florida, Montreal, New Orleans, etc.). The Jazz Ensemble plays concerts on campus, at festivals, and on tour during both the fall and the spring semesters.

Performances by the string orchestra and the ensembles traditionally close the semester concert season. The ensembles include groups of string, brass, woodwind, percussion and mixed instruments. Recent additions have been ensembles of Renaissance instruments from the university collection.

The Lehigh University Very Modern Ensemble (LUVME) combines students, faculty, and professional musicians who perform the music of the 20th Century. LUVME also sponsors concerts of music by Lehigh student composers and annually brings a composer of national reputation to campus in order to discuss and play his/her music.

The "97" marching band is widely known for its imaginative and spirited performances on the gridiron and in the stands in support of the Lehigh football team. Pregame and half-time performances are precision drills with a varied repertoire from classical music to traditional fight songs. The band is comprised of 97 men and women with nine students serving in executive positions.

The concert series Music at Lehigh presents a variety of concerts and recitals. Among the artists who have appeared are the Orpheus Chamber Orchestra; Calliope: A Renaissance Band and Dawn Upshaw, Met soprano. Inaugurated in 1980, the Ralph Van Arnam Chamber Music Series presents concerts of outstanding chamber music; the series honors the memory of a Lehigh faculty member.

Private instrumental and vocal lessons with instructors approved by the music department are open to all students. The cost of lessons is in addition to tuition expense.

## Volunteer Services

Varied opportunities for student expression of social responsibility exist through programs sponsored by the Lehigh University Volunteers (LUV). Typically, more than 100 students participate in volunteer-service efforts in the Lehigh Valley area in a range of service programs. LUV is governed by a board composed of coordinators of its various projects.

Most of the volunteer work is done in cooperation with community agencies or schools. Some of the projects include tutorial programs in public and private schools, assistance in local hospitals, Big Brothers, companionship, fund raisers for national charities, affiliation with Habitat for Humanity which is an organization to help the homeless and needy people, aid to the elderly in institutions, blood assurance, and individual and short-term efforts.

LUV's office is located in Packer Hall, the university center.

## Guest Speakers

Students have the opportunity to hear a wide variety of notable speakers. The speeches are offered free of charge. Many of the speakers appear under the auspices of the Visiting Lecturers Committee. Committees with access to special funds and academic departments regularly offer presentations by scholars from various disciplines. In addition to delivering a formal address, the speakers are often invited for brief residencies to provide opportunities for more informal interaction with students.

Among those to visit the campus have been attorney F. Lee Bailey, philosopher Derek Parfit, actor Vincent Price, South Africa's Bishop Desmond Tutu, and novelist John Irving. Thomas Armstrong, director of the Whitney Museum, spoke with students during a week-long residency. An Engineering Expo with speakers representing many prominent industries featured Peter Bridenbaugh, vice president of science and technology, Alcoa. From art to engineering, the campus stays in touch with current issues, trends, and movements through its many and varied speaker series.

# Athletic Opportunities

Students can participate in many intercollegiate, recreation, and intramural athletic programs.

Intercollegiate, varsity-level sports include the following. FALL: football, men's and women's cross-country, soccer, women's field hockey, and women's volleyball and tennis. WINTER: Men's and women's basketball, wrestling, men's and women's indoor track and swimming. SPRING: Baseball, tennis, golf, men's and women's outdoor track, and lacrosse and women's softball.

Athletic facilities are located in Taylor Gymnasium and Grace Hall and on the Murray H. Goodman campus, which is located two miles south of the main campus. The 500-acre Goodman athletic complex includes the Stabler Athletic and Convocation Center, which seats 6,000 and hosts most of Lehigh's wrestling matches and basketball games. The campus also contains the Philip Rauch Field House, which includes a one-eighth-mile track and indoor tennis and basketball courts. A 13,600 seat stadium for football and soccer has been added. Other facilities on the campus include a championship cross-country course, baseball and softball fields, indoor squash courts, tennis courts, lacrosse and field hockey fields, and an all-weather, eight-lane, outdoor 400-meter track.

Lehigh is affiliated with the National Collegiate Athletic Association (NCAA), the East Coast Conference (ECC), the Eastern College Athletic Conference (ECAC), and the Colonial League. Lehigh frequently hosts championship events in men's and women's sports.

## Intramural Athletics

The department of intramural sports and recreation supervises some 26 intramural sports and the recreational physical activities of students. The aim is to insure the health and physical development of students.

Through its program of intramural sports, the university endeavors to maintain among its students a high degree of physical fitness, to establish habits of regular and healthful exercise, to foster the development of such valuable byproducts as self-confidence, good sportsmanship, and a spirit of cooperation, and to provide each student with ample opportunity for acquiring an adequate degree of skill in sports of the type in which participation can be continued after graduation.

On a club-level, there are from 20 to 25 common-interest groups ranging from karate and judo to Frisbee and floor hockey. Students are encouraged to pursue their special interests.

Also available are instructional classes in aerobics, flexercise, and skiing, in addition to such special tournament events as foosball, co-rec volleyball, and three-on-three basketball. The intramurals office provides picnic bags filled with bats, softballs, and other recreational equipment. The facilities in Taylor Gymnasium and Philip Rauch Field House are also available at listed times.

# Guide to Academic Rules and Regulations

The university, like the rest of society, has adopted over the years numerous rules and regulations. Some of the principal rules and regulations are given here so that currently enrolled and potential undergraduates and graduate students will be apprised of what is expected of them, and what they can expect of the university.

This section concerns academic regulations. Additional regulations can be found in the *Lehigh Handbook*, and there is a comprehensive statement of all policy in the publication *Rules and Procedures of the Faculty*. All students are given a *Handbook* at the beginning of the fall semester; *Rules and Procedures* is available in the university libraries and in departmental and administrative offices.

## Eligibility for Degree

In order to be graduated, a candidate for a baccalaureate degree must achieve a minimum cumulative average of 2.00.

To be eligible for a degree, a student must not only have completed all of the scholastic requirements for the degree, but also must have paid all university fees, and in addition all bills for the rental of rooms in the residence halls or in other university housing facilities. Payment also must have been made for damage to university property or equipment, or for any other indebtedness for scholarship loans or for loans from trust funds administered by the university.

**Responsibility for meeting requirements.** A student is responsible for consulting with the academic adviser or department chairperson, prior to the senior year, to ascertain scholastic eligibility for the degree for which this student desires to qualify and to determine that all program and credit hours requirements will be met.

**Final date for completion of requirements.** For graduation, all requirements, scholastic and financial, must have been satisfied prior to the graduation exercises.

## Notice of Candidacy for Degree

Candidates for graduation on University Day in May or June file with the registrar on or before March 2 a written notice of candidacy for the degree; candidates for graduation in January file a notice of candidacy on or before December 1; candidates for graduation on Founder's Day, the second Sunday in October, file a notice of candidacy on or before September 1.

Failure to file such notice by such dates mentioned debars the candidate from receiving the degree at the ensuing graduation exercises. If a petition for late filing is granted, a fee is assessed.

## Graduating Theses

Undergraduate theses, when required, are accompanied by drawings and diagrams, whenever the subjects need such illustration. The originals are kept by the university, as a part of the student's record, for future reference; but copies may be retained by students and may be published, provided permission has first been obtained from the faculty.

## Undergraduate Credit and Grades

A semester hour of college work consists of one hour a week of lectures or classwork, or two or three hours of laboratory work per week (or laboratory work combined with classwork) for one semester. The normal assumption is that the student will be expected to do at least two hours of study in preparation for each hour of classwork. The term "semester hour" is used interchangeably with "credit hours."

**Latest date for registration.** No registration is accepted later than the tenth day of instruction in any semester.

**Definitions of grades.** Course grades are A, A−, B+, B, B−, C+, C, C−, D+, D, D−, P, F, N, and X. The meaning of each grade is as follows: A, A−, excellent; B+, B, and B−, good; C+ and C, competent; C−, continuation competency (the student has achieved the level of proficiency needed for the course to satisfy prerequisite requirements); D+, D, and D−, passing, but in the estimate of the teacher, the student may not be adequately prepared to take any subsequent course that has the teacher's course as a prerequisite. A student must obtain his or her adviser's permission to use courses in which a grade of D+, D, or D− is received to meet prerequisite requirements; P, pass-fail grading with a grade equivalent to D− or higher; F, failing; N, incomplete; X, absent from the final examination; XN, absent from the final examination and incomplete.

Other symbols used for courses on student records are: Cr, credit allowed; W, withdrawn; WP, withdrawn with permission and with passing performance at the time of withdrawal; WF, withdrawn beyond the deadline and/or with failing performance.

Grades in the range of A through D−, P, and Cr may be credited toward baccalaureate degrees within the limits of program requirements. Grades of F, N, X, XN, W, WP, and WF cannot be credited toward the degree. Grades of F and WF that have not been bettered through repetition of the course must be included in computation of hours attempted. Grades of W and WP do not count as hours attempted.

Courses in which grades of F, W, WF, N, X, or XN are recorded do not meet prerequisite requirements.

The grade N(grade) may be used to indicate that one or more course requirements (e.g., course report) have not been completed. It is the obligation of the student to explain to the satisfaction of the instructor that there are extenuating circumstances (e.g., illness or emergency) that justify the use of the N grade. If the instructor feels the N grade is justified, he or she assigns a grade of N supplemented

by a parenthetical letter grade, (e.g., N(C)). In such cases, the instructor calculates the parenthetical grade by assigning an F (or zero score) for any incomplete work unless he or she has informed the class in writing at the beginning of the course of a substitute method for determining the parenthetical grade.

In each case in which an N grade is given, the course instructor shall provide written notification to the department chairperson stating the name of the student receiving the grade, the reason for the incomplete work, the work to be done for the removal of the N grade and the grade for the work already completed.

A student who incurs an N grade in any course is required to complete the work for the course by the fifth day of instruction in the next academic-year semester. The N grade will be converted into the parenthetical grade after the tenth day of instruction in the next academic-year semester following receipt of the N grade unless the instructor has previously changed the grade using the removal-of-incomplete procedure. The parenthetical grade will be dropped from the transcript after the assignment of the course grade.

In no case shall the grade N be used to report absence from a final examination when all other course requirements have been met.

N grades do not count as hours attempted and are not used in computations of cumulative averages.

The grade X (grade) is used to indicate absence from the final examination when all other course requirements have been met. The grade in parenthesis is determined by including in the grade calculation an F (or zero score) for the missing final exam. The X grade may be removed by a make-up examination if the absence was for good cause (e.g., illness or other emergency). To be eligible for the make-up exam, the student must file a petition and the petition must be approved by the committee on standing of students. If the student fails to petition, or if the petition is not granted, or if the student fails to appear for the scheduled make-up examination, then the X grade will be converted into the parenthetical grade after the first scheduled make-up examination following the receipt of the X grade. If the petition is granted and the final examination is taken, the X grade will be changed by the instructor using the make-up examination procedures and the parenthetical grade will be dropped from the transcript.

Where there are valid reasons for not taking the make-up examination at the scheduled time, the student may petition for a later examination with a fee.

The grade XN (grade) is used to indicate both absence from the final examination and incompletion of one or more course requirements. The instructor calculates the parenthetical grade using an F (or zero score) for the final examination and either an F (or zero score) or the substitute method of calculation as described above for the incomplete work.

The XN grade may be removed by the procedures presented in the previous paragraph for removing the X grade. If this results in an N grade because the course work is still incomplete, the provisions Incomplete (N grade) above shall apply, except that in no case shall the deadline for completion of the work be later than the last day of classes in the first full semester in residence (except summer) following receipt of the XN grade.

Where failure to complete coursework prevents the student from taking the make-up examination at the scheduled time, the student may petition the committee on standing of students for a later examination.

An XN grade that is still outstanding after the tenth day of instruction in the next academic-year semester following receipt of the XN grade will be converted into the parenthetical grade. The parenthetical grade will be dropped from the transcript.

X and XN grades do not count as hours attempted and are not used in computations of cumulative averages.

A withdrawal from a course within the first ten days of instruction is not recorded on the student's record.

A student wishing to withdraw from a course after the tenth day, but not after the ninth week of instruction, must proceed as follows: The student indicates intention in writing to withdraw from the course, giving the course number, title, and credit hours;the student presents the drop and add form to the adviser and the course instructor. Each signs the form to indicate that he or she has seen it and discussed it with the student, and notes appropriate recommendations; the signed form is delivered to the registrar. He or she records a W for the course and the date of withdrawal on the student's transcript.

A student who officially withdraws from the university through the ninth week of instruction receives grades of w in the courses for which he or she is registered. Thereafter, each course instructor assigns a grade of WP or WF.

A student who withdraws from a course but not the university after the ninth week of instruction will automatically receive a WF for the course.

A student who reduces his or her course load below the minimum required for standing as a full-time student but does not withdraw from the university becomes a part-time student for the rest of that semester. Some areas affected by part-time status are financial aid, athletic eligibility, veterans affairs, selective service, and immigration status.

Official reports of grades are issued to advisers and students by the registrar as soon as possible following the deadline for reporting of grades. Instructors may develop their own policies for release of unofficial reports of academic progress to individual students, or to their advisers, deans, or financial aid officers, on a need-to-know basis, including early release of unofficial final course grades. Any such policies must respect the rights of students to privacy.

A report of grades is sent to each student's home at the end of every semester.

## Graduate Credit and Grades

Course grades are defined as for undergraduates except that no grade lower than C− may be counted toward a graduate degree and pass-fail registration is not allowed for graduate students. No student who receives more than four grades below a B− in courses numbered 200 or higher is allowed to continue registration as a graduate student.

The N grade is defined as for undergraduates except that graduate students have a calendar year to remove course incomplete grades unless an earlier deadline is specified by the instructor. Graduate student incomplete course grades that are not removed remain as N grades on the student's record. Thesis or research project N grades may remain beyond one year until the work is completed.

The X grade is defined as for undergraduates except that to be eligible for a make-up examination a graduate student must file a petition and the petition must be approved by the graduate committee.

The XN grade is defined as for undergraduates except that graduate students have a calendar year to complete coursework following an XN grade unless an earlier completion deadline is specified by the instructor. The X portion of the grade is removed as described for undergraduates. XN grades which are not removed remain on the record of graduate students. All petitions for exceptions are sent to the graduate committee.

A withdrawal from a course within the first ten days of classes is not recorded on the student's record.

A student who wishes to withdraw from a course after the tenth day, but not after the ninth week of instruction, receives a grade of W. A student who withdraws after the ninth week period will receive a WF or WP at the discretion of the instructor.

A student withdrawing from a course submits a department approved change of roster form to the Graduate School office.

## Pass-Fail Systems for Undergraduates

**Student Option System.** The pass-fail grading option is intended to encourage students to take challenging courses outside the major field that otherwise might be avoided for fear of lowering grade-point averages. Students should avoid wasting this option on unsuitable courses, such as introductory courses having no college-level prerequisite or corequisite. The restrictions on the use of the system are listed below.

A student may register for no more than two courses pass-fail in any one semester. He or she may take a maximum of six courses pass-fail per undergraduate career if the student is on a four-year program, or a maximum of eight courses per undergraduate career with a five-year, two-degree program. If a student changes a course after the first ten days of instruction from pass-fail grading to regular grading, as provided below, that course shall still count toward the maximum number of courses taken pass-fail during the student's undergraduate career.

Each college faculty shall decide under what conditions and which

courses or categories of courses throughout the university may be taken for pass-fail credit by students registered in that college, except for courses designated specifically for pass-fail grading. Each college shall keep the educational policy committee advised of changes in its rules.

A student designates the course(s) to be taken pass-fail normally at preregistration but not later than the tenth day of instruction in a regular semester or the fifth day of instruction in any summer session. Prior to this deadline, the student may transfer from pass-fail to regular grading, or vice-versa, without penalty. After this deadline, the student cannot transfer from regular grading to pass-fail grading; however, the student may transfer from pass-fail grading to regular grading through the ninth week of instruction. The courses designated for pass-fail grading by the student require the written acknowledgement of the academic adviser.

The instructor giving the course is not officially notified which students are taking the course pass-fail. Therefore, a regular letter grade is reported for the pass-fail students. The registrar then records "P" for reported letter grades from A through D−, and "F" for a reported letter grade of F.

Under this system, the student surrenders his or her equity to letter grades of A through D−, except as specified below. A grade of P applies to the student's graduation requirements but is not used in the computation of the cumulative average. An F grade is computed in the normal manner.

If a student changes his or her program such that a course previously taken for pass-fail grading is not allowed for pass-fail grading in the new program, the student must submit a petition to the committee on standing of students requesting acceptance by the new program of the pass-fail grading for that course, or substitution of the original letter grade submitted by the instructor for the pass-fail grade, or the substitution of another course for the course taken pass-fail. The recommendation of the adviser must accompany the petition.

Courses at the 400 level are excluded from pass-fail grading.

## Scholastic Averages and Probation

Scholastic requirements for undergraduate students are expressed in terms of the cumulative average—the weighted point average of all grades received in residence or at institutions specifically approved for grade transfer. The cumulative average is computed at the end of each semester and the second summer session. Following are the cumulative average requirements for good standing (effective with the class of 1992):

| | |
|---|---|
| freshmen (1st semester) | 1.60 |
| freshmen (2nd semester) | 1.70 |
| sophomores | 1.80 |
| juniors and seniors | 2.00 |

For purposes of computation, students who have completed fewer than 6 credit hours of coursework shall be required to maintain a 1.60 average to remain in good standing. Students who have completed 6 hours but fewer than 22 hours shall be required to maintain a 1.70 average. Students who have completed 22 hours but fewer than 52 shall be required to maintain a 1.80 average. Other students shall be required to maintain a 2.00—the average required for graduation—to remain in good standing.

Students who do not meet the above requirements will be placed on scholastic probation. Students who, regardless of their cumulative average, have failed more than eight hours of course work in any semester are also placed on scholastic probation.

While there are no hours requirements for good standing, certain categories of students (e.g., those on financial aid and those playing intercollegiate athletics) will be expected to maintain whatever hours are required for eligibility.

**Removal from probation.** Students are removed from probation at such time as they meet the standard listed above, effective at the end of any semester or the second summer session.

**Dropped for poor scholarship.** A student who makes a 2.2 average or better in the probationary semester but fails to meet the standards stipulated is continued on probation for another semester. A student who makes less than a 2.2 average in the probationary semester and fails to meet the standards stipulated above, is dropped for poor scholarship.

If a student goes on scholastic probation for the second but not consecutive term, a review by the committee on standing of students will determine whether the student will continue on scholastic probation or be dropped for poor scholarship.

## Honors Opportunities

There are several kinds of honors awarded to undergraduates. Each department offers departmental honors to qualified students and each college offers an honors program as well; more information is contained in Section III.

**Graduation honors.** Degrees *with honors* are awarded by vote of the university faculty to those students who have attained an average of not less than 3.25 in their sophomore, junior, and senior years of work at the university, and in not less than seventy-two hours of work graded A, B, C, D, or F.

Degrees *with high honors* are awarded by vote of the university faculty to those students who have an average of not less than 3.50 in their sophomore, junior, and senior years of work at the university, and in not less than seventy-two hours of work graded A, B, C, D, or F.

Degrees *with highest honors* are awarded by vote of the university faculty to those students who have an average of not less than 3.75 in their sophomore, junior, and senior years of work at the university, and in not less than seventy-two hours of work graded A, B, C, D, or F.

Graduation honors are announced on University Day and on Founder's Day.

**For special cases.** Students who spend all or part of their sophomore, junior, or senior years at another institution may qualify for graduation honors under the following conditions:

1. The student must have at least ninety credit hours of work at Lehigh and an average during the last six semesters in residence at Lehigh that qualified him or her for graduation honors. This average determines the highest category of graduation honors that is possible for the student to attain.

2. The student's average at the other institution when computed with the last six semesters at Lehigh must be such as still to qualify the student for graduation honors. This average may lower the over-all average of the student from one category of graduation honors to another one.

Graduation honors are published in the commencement program.

In all cases, it is required that each student have not less than seventy-two hours of work graded A, B, C, D, or F, including plus + or minus − designations.

In computing the averages of candidates for graduation honors, semester grades are weighted according to the number of credit hours in the course concerned.

## Review-Consultation-Study Period

The Review-Consultation-Study (RCS) period is intended to provide a few days for informal academic work between the end of the formal instruction period and the beginning of the final examinations.

It is expected that students will use this period to consolidate their command of the material in their courses. Faculty members make themselves available to their students at announced times during the period; for example, at the hours when they ordinarily meet classes for instruction.

No quiz may be given during the eight-day period before examinations.

# Good Citizenship

The university exists for the transmission of knowledge, the pursuit of truth, the development of students, and the general well-being of society. Free inquiry and free expression are indispensable to the attainment of these goals. All members of the academic community

are encouraged to develop the capacity for critical judgment and to engage in a sustained and independent search for truth.

Out of concern for individuality and respect for the privacy of all persons, the university does not impose a common morality on its members. Institutional existence, however, is a privilege granted by public trust, subject to the sanctions and responsibilities defined by the society of which the university is a part.

Furthermore, society generally provides legal canons, ethical mores, and conduct expectancies pertaining to individual and collective behavior. Thus, the university has the obligation to establish standards of conduct appropriate and applicable to the university community.

Lehigh accepts its responsibility as an institution within the broader social community. The standards of behavior expected of its members are those that the university regards as essential to its educational objectives and to community living.

In accordance with these purposes and objectives, disciplinary action will be taken when necessary to protect the academic integrity of the university and the welfare of its members.

All members of the university community are subject to municipal, state, and federal laws. Obviously the university cannot be a sanctuary for persons who violate these laws. Lehigh is concerned, however, about the rights of students as citizens and will direct them to legal counsel when necessary.

While off-campus misconduct will not normally be the basis for disciplinary action, where the university has an identifiable interest separate from that of the off-campus community, such conduct may be subject to disciplinary review and action by the university.

Further, the university as a part of the community has an obligation to report serious crimes to civil authorities.

Lehigh relies primarily on general principles and statements of expectation for standards of conduct, and assumes that those admitted to the university community are capable of accepting that responsibility. Specific regulations are kept to a reasonable minimum and are published in the *Lehigh Handbook*. Students are responsible for knowing the procedures, rules and regulations as published in the *Handbook*.

## Policy on Dissent

Regarding dissent, the university faculty has a policy that emphasizes the responsibility of all members of the university community. The guidelines adopted broadly set forth acceptable forms of dissent on campus.

Generally, the policy on dissent provides the following:

1. Free inquiry and free expression, including the right to open dissent, are indispensable in achieving the goals of an academic community.

2. Coercive activities employed by individuals or groups either to repress legitimate dissent or to demonstrate dissent are a threat to the openness of the academic community and will be dealt with as an extremely serious matter.

3. Where physical coercion is employed or physical obstruction persists and the university is prevented from resolving the matter through its established disciplinary procedures, legal sanctions will be employed.

This statement provides that orderly and peaceful demonstrations on campus are not forbidden unless they interfere with legitimate university functions. The authority for making the initial judgment in determining the permissible limits of protest rests with the president and counsel of an advisory committee consisting of four faculty members and four students.

Conduct that exceeds permissible limits will be met with university sanctions ranging in severity from admonition to expulsion, or in cases of aggravated or persistent violation of defined rights, with civil arrest and prosecution under an appropriate charge. Prime authority for discipline rests with the faculty and the university committee on discipline.

## Nontraditional Students

Adults and other nontraditional students who desire access to regular university courses have a number of options available.They may apply for admission to an undergraduate or graduate degree program on a full or part-time basis.

If they need to take one or more courses for credit, but are not seeking a degree, they may seek admission to the General College Division on the undergraduate level or become associate graduate students on the graduate level.

# II

## University Resources

*"Everything I learned at Lehigh wasn't in the books. From my fraternity, the jazz ensemble, the marketing and investment clubs I learned how to deal with people and manage my life. When I graduated, I was better prepared to manage others, and I felt ready for the world."* – Dave Fiore, Lehigh alumnus.

# II.

# University Resources

A student enrolled at an institution of the size and tradition of Lehigh can draw upon many resources to enhance the educational experience. These range from classrooms and laboratories with modern equipment to expert faculty members and extensive library collections. Indeed, university's 1,600 acres comprising its three Bethlehem classes are a special resource, providing a beautiful environment for learning. Following are descriptions of various resources related to academic programs.

## Collections and Computers

The directness of the printed word, the vision of art, and the power of data processing all play important roles in a broad, liberal education. University collections and facilities place a wealth of information at the student's disposal.

### Libraries

The university library system serves as an essential element in the educational process, providing users access to information not only through an extensive book and journal collection numbering more than 920,000 volumes, but through electronic data bases, microform, computer software, and media collections as well.

In 1986, the libraries completed the transformation from the traditional paper library to an electronic information center. Users access the on-line catalog, known as ASA (Automated System Access), from every residence-hall room, every faculty office, classrooms, and laboratories, via the campuswide network. From these same locations, the newly acquired CURRENT CONTENTS database provides access to tables of contents of over 7,000 periodicals, covering all subject areas, on the network. Users also obtain worldwide access to several hundred national and international electronic data bases. Via the campus-wide network, users can also submit reference inquiries, place orders, and request media services; request delivery of documents electronically.

#### *Facilities and Collections*

With the opening in 1985 of the E.W. Fairchild-Martindale Library and Computing Center, adjoining the Mart Science and Engineering Library, the combined information center merged more than 300,000 volumes in the social sciences with a 200,000-volume collection in the natural and physical sciences, mathematics, and all branches of engineering. The new facility, which has a total capacity of 650,000 volumes, also houses government documents and business collections.

The historic Linderman Library, part of which was built in 1877, is dedicated to all branches of the humanities. A collection of 380,000 volumes encompasses strengths in British colonial history, and American and English literature. The Bayer Galleria of Rare Books, which opened in 1985, embraces the university libraries' Special Collections Division, estimated to include about 24,000 volumes. Included here are the extensive rare-book collections, many of which were donated by the libraries' benefactor, Robert B. Honeyman, as well as university archives, and Congressional papers. Noteworthy among the treasures in the rare book collection are an original edition of John James Audubon's *Birds of America* and three copies of the first edition of Charles Darwin's *Origin of Species*.

#### *Resources*

Library holdings represent a rich resource for the university community. In addition to the collection of 920,000 volumes, the libraries receive more than 9,200 periodicals and serials, including a well-developed foreign and domestic newspaper collection. Another important research tool is the government documents collection. A partial government depository since the 19th Century, the libraries hold more than 400,000 federal, Pennsylvania, and United Nations documents, as well as a vast collection of technical reports from governmental agencies.

Nonprint collections of nearly 1,500,000 microforms and 19,000 audiovisual resources enhance the traditional book and journal collections. The David M. Greene music collections includes several thousand tapes and cassettes of classical music. The libraries also have a wide range of reference sources in all fields on compact disk. These CD-ROM databases offer yet another alternative for the retrieval of current literature.

University library resources are augmented by memberships in the Lehigh Valley Association of Independent Colleges; PALINET, Pennsylvania Area Library network; IDS, Interlibrary Delivery Service of Pennsylvania; OCLS, Online Computer Library Center; as well as the International Association of Technological University Libraries.

#### *Services*

The university library staff, numbering 74 full-time and part-time employees, serves the needs of faculty and students by providing programs that stimulate the use of the information system as a vibrant intellectual resource. Helpful personal assistance is available from staff in such areas as computer searching of remote data bases, instruction in research bibliographic methodology, library orientation, current-awareness services, and interlibrary loans.

The advent of the campuswide network and the ease of accessing electronic information has enabled the library to supply all users with electronic services as well as traditional services. Users can order material—including photocopies and interlibrary loans—and submit electronic reference inquiries and obtain media services via the network 24 hours a day. The reference staff has been providing a major instructional effort for end-user searching of both local and remote data bases.

As a convenience to the university community, the libraries have available 75 general-access microcomputers; photocopies; and calculators.

The Lehigh libraries are fully automated. Since 1985, when the libraries implemented a Geac Integrated Library System, the traditional card catalog has been replaced with ASA, the on-line catalog, and an on-line circulation system. Acquisitions, cataloging, and serials functions are also automated.

As a service to the extended community of alumni and regional corporations, the libraries sponsor a fee-based information service for business, industry, and government. A Friends of the Libraries program has also been in existence since 1981. The Friends

programs provide another vehicle for university cultural activities in the forms of lectures, concerts, and exhibits.

The libraries are open 108 hours per week and, during the academic year, are open from 8 a.m. to midnight, Monday through Saturday, and noon to midnight on Sunday.

### *Media Center*

University media services are represented by three modules. The Fairchild-Martindale Media Center provides opportunities for individual and group listening and viewing of audio and video tapes, cassettes, records, slides, and films, in a collection numbering more than 9,000 units. In addition, selected computer software is available for loan or use by the university community. The center includes an electronic classroom; general-purpose access microcomputers; and videodisk player.

Media production services, located in the Linderman Library, offer a full spectrum of activities, including video and audio production; photographic services; slide preparation; and graphics. Consulting is also available for preparation and handling of equipment.

Audiovisual services prepare identification cards, handle the equipment needs for public affairs, and serve selected instructional needs for equipment.

## Networking

The university has an InteCom digital PBX system that provides integrated voice and data communication services throughout the campus. Each room in the student residence facilities is equipped with a telephone to be used for on-campus, local, and long-distance services.

Students who own microcomputers are able to use the university network services over the same phone line. Students who do not own microcomputers may use any of approximately 250 Zenith microcomputers distributed in sites across the campus. The system provides access to the Computing Center mainframe computers, the Integrated Library System, and other computers located on the campus.

Each member of the university faculty is equipped with a Zenith microcomputer, which facilitates the academic use of the network in the instructional process.

Students may purchase Zenith microcomputers at the university's Microcomputer Store. Students or prospective students who are considering the acquisition of a microcomputer other than a Zenith should consult members of the Computing Center staff to insure compatibility with the university's network system.

## Computing Center

With its distinguished heritage of teaching and research in engineering and science, Lehigh has made extensive use of computers for more than two decades. In response to the need for an independent organization to serve the diverse needs of the academic community, the Computing Center was formed in 1966. Today, the center serves existing needs while anticipating and preparing for the future requirements of its user community.

The Computing Center, located in the E.W. Fairchild-Martindale Library and Computing Center, serves as a laboratory for departmental courses and research in computer theory and applications, including developmental programs. It provides computing services to all university departments and research centers for instructional, research, and administrative applications.

The central computing facility houses a Control Data Corp. CYBER 180 model 850; a Digital Equipment Corp. VAX 8530, and two International Business Machines Corp. 4381 systems, one of which is used exclusively for administrative processing.

The CYBER 180 model 850 is equipped with 4 megawords (64 bits per word) of central memory, 6.9 gigabytes of on-line disk storage, 80 asynchronous ports, one synchronous port, two nine-track magnetic tape drives, one 2,000-line-per-minute printer, a CalComp 1012 plotter, and a Hewlett-Packard 7586B publication-quality plotter. The principal high-level programming languages available on the system are FORTRAN, COBOL, and Pascal. In addition, various simulation packages, special-purpose languages, and applications packages are provided.

The VAX 8530 is equipped with 64 megabytes of main memory, 2.5 gigabytes of on-line disk storage, 72 asynchronous ports, one nine-track tape drive, and one 40-page-per-minute laser printer. The principal high-level programming languages available include FORTRAN, COBOL, Pascal, AC, and BASIC. A data-base management system (DBMS-20) is supported, as are utilities primarily oriented to interactive computing.

The administrative IBM 4381, model 11, is a 32-bit, virtual storage-based machine with eight megabytes of memory. The system is equipped with two nine-track tape drives, ten gigabytes of disk storage, and a 1200-line-per-minute printer. COBOL is the primary high-level programming language available on the system.

The IBM 4381 model 13, is part of a joint development project with IBM and is aimed at adapting the system to the networking needs of the campus. The system is a 32-bit, virtual storage-based machine with 16 megabytes of memory, 10 gigabytes of disk storage, 200 asynchronous ports, two cartridge tape drives, a 1200-line-per-minute printer, and a 20-side-per-minute double-sided laser printer.

In addition to these systems, the Computer Center maintains approximately 250 Zenith microcomputers in sites across the campus. The center operates five microcomputer classrooms, each equipped with approximately 15 microcomputers and a large-screen projection system. In addition to the local area networks installed at most sites, all of these microcomputers have the capability to connect to any other computer on campus by means of the InteCom communications system.

### *Research Activities*

To preserve its role of impartial support for all users, the center does not engage in primary research. It has, on occasion, conducted research-related activities on its own or in cooperation with academic departments and research centers. However, approximately one-quarter of its computer utilization is devoted to supporting the computing activities of the research community.

In the past, research activity using the computer has been associated largely with the College of Engineering and Applied Sciences. Recently, however, use of the computer has expanded because of increased application of computers to disciplines in the College of Business and Economics, the College of Arts and Science, and the College of Education. Research centers and departments including the Sherman Fairchild Laboratory for Solid-State Studies, the department of mechanical engineering and mechanics, the department of industrial engineering, and the department of physics find computers helpful in the collection and analysis of laboratory and survey data, and in modeling using this data. With the advent of networking technology, communications between the center and other areas of the campus has increased dramatically.

### *Educational Opportunities*

Seminars on various topics related to data processing in computing are held or sponsored by the center for faculty, staff, and students. Students desiring a more intensive educational experience in an operating environment may apply for part-time jobs in programming, user services, and operations. The center works closely with the Computer Society to meet the more independent inquiry needs of undergraduates. The society's adviser is usually a member of the center staff.

The center offers educational opportunities in the use of computers by providing computing resources for the academic community. More than one-third of the center's activity is devoted to instructional computing. Most jobs processed by the center are submitted by students as part of their normal academic coursework. The growth of interactive processing and personal computers facilities benefits these users. LUCC has prepared a general guide to its computing facilities and services, entitled "Introduction to the Lehigh University Computing Center." This guide can be obtained free of charge by writing to User Services, Fairchild-Martindale Computing Center, Building 8B, Lehigh University, Bethlehem, Pa. 18018, or by calling (215) 758-3990.

## Art Galleries; Museum Operation

The Lehigh University Art Galleries maintain and develop the university's permanent art collection, as well as present temporary exhibitions designed to make visual literacy a result of the university learning experience. More than twenty exhibitions a year in three campus galleries introduce students and the community to current topics in art, architecture, history, science, and technology. The exhibition schedule is supplemented by lectures, films, workshops, and opportunities for research in the permanent collection. Through exhibitions and programs, the art galleries play an important role in the educational mission of the university.

The art galleries occupy exhibition, storage, office and workshop space in several campus locations. The Ralph L. Wilson and Hall galleries are located in the Alumni Memorial Building; Maginnes Hall houses the DuBois Gallery; Mountaintop Gallery, Building A; and the administrative office and workshop are in Chandler-Ullmann Hall. The Muriel and Philip Berman Sculpture Gardens are located in the courtyard of Mudd, Mart, Whitaker and Sinclair; Saucon Field, Murray H. Goodman Campus and Mountaintop Campus.

### *Exhibitions*

Exhibitions and gallery events are planned to supplement formal classroom study in the visual arts, to create educational opportunities for the entire student body, and to enrich the cultural life of the campus and the community at large. The annual schedule includes the exhibition of works from the permanent collection, the use of borrowed objects, and the rental of traveling exhibitions from major museums and cultural institutions. Experts in various fields serve as guest curators of special project exhibitions. In addition, interdepartmental projects within the university lead to increased involvement by faculty and students. Undergraduates may take advantage of courses in museum studies as well as independent study in the collection.

### *Collections*

Lehigh University's permanent art collection is a working and study collection intended as a resource for students pursuing formal study in the visual arts or museum studies, for the faculty, and for interested members of the community. Each year, several exhibitions are prepared from the collection. Individual works from the collection have recently been loaned to major museums throughout the nation.

The permanent art collection consists of a variety of works by old masters and contemporary artists. Important collection groups include: the Marion B. Grace Collection of European Paintings (Gainsborough, Reynolds, Goya, Hobbema, Hoppner, and others); the Dreyfus Collection of French Paintings (Bonnard, Sisley, Vuillard, Courbet); the Ralph L. Wilson Collection of American Art (paintings by Prendergast, Sloan, Henri, Lawson, Bellows, Davies, Burchfield; prints by Whistler, Hassam, Motherwell, Johns, Rauschenberg, Calder, Warhol); the Prasse Collection of Prints (Delacroix, Matisse, Renoir, Kent, Kunyoshi, Rivera); the Philip and Muriel Berman Collection of Japanese Prints (Hiroshige, Hokusai, Munakata, Utamaro) and the Philip and Muriel Berman Collection of Contemporary Sculpture.

Also, the Fearnside Collection of European Old Master Prints and Drawings; the Baker Collection of Chinese Porcelains; the Langermann Collection of Pre-Columbian Sculpture; the Mr. and Mrs. Franklin H. Williams African Collection (gold weights of the Akam and West African objects); the Lehigh University Photography Collection (Bravo, Hine, Weston, Porter, Rothstein, Harvan, Rau, Stoumen, Arbus, Bourke-White, Brassai, Fink, Callahan, Edgerton, Cameron, Abbott, Sander, Winogrand); and the Lehigh University Contemporary Prints Collection (Bearden, Rivers, Anusziewicz, Soto, Roth, Chryssa, Ruscha, Tobey, Calder, Kitaj, Marca-Relli, Genoves).

## Lehigh University Press

The Lehigh University Press represents a clear expression of faculty and institutional commitment to the advancement of scholarship. Stephen H. Cutcliffe, director of the Science, Technology, and Society Program, serves as director of the press, and members of the faculty of the four colleges serve on its editorial board.

Although the press will publish fine scholarship in all disciplines and fields, special emphasis is given to areas with traditional strength at Lehigh: science, technology and society studies; economics and business studies, and 18th century studies. The press is also interested in attracting manuscripts that deal with eastern Pennsylvania and the Lehigh Valley.

The university press brings Lehigh's name to the attention of the world of scholarship in a new way. Linking the name of the university to a list of fine work by scholars throughout the country helps reinforce the academic environment for faculty, graduate students, and undergraduates. Lehigh's alumni can also maintain intellectual contact with the university through its press.

Volumes published in 1988 included *In Context: History and the History of Technology — Essays in Honor of Melvin Kransberg* edited by Stephen H. Cutcliffe and Robert C. Post and *A Literary History of New England* by Perry Westbrook. Expected volumes for 1989 will include *My life with the Printed Circuit* by Paul Eisler, inventor of the printed circuit, and *Science, Technology and Social Progress*, edited by Steven L. Goldman, Lehigh's Andrew W. Mellon Professor in the Humanities.

For more information, contact Stephen H. Cutcliffe, Maginnes Hall, Lehigh University, Bethlehem, Pa. 18015.

# Resources for Students

Lehigh's administrators firmly believe that the interrelationship between students' classroom and nonclassroom activities can be fostered to become an educational avenue through which students grow, accept responsibility, and gain maturity in ways that will contribute to productive and meaningful lives. Through various services, students are assisted in becoming informed decision makers. They are also encouraged to develop greater self-awareness and self-confidence in their ability to lead the lives they choose.

General counseling of individual students often begins in the residential setting. Staff members in the residence halls include two live-in professionals, eleven graduate students who are hall directors, and approximately eighty undergraduate residence hall counselors, known as Gryphons. All staff members are carefully selected, extensively trained, and are available to assist resident students who may have a variety of concerns.

Students are also encouraged to seek counsel and guidance from professionals in many areas of student life. The Office of the Dean of Students serves as a central agency to help students who have questions about academic and procedural matters, personal problems, legal problems, and other general concerns, both through its staff and through referral to other student affairs and academic offices.

Students who need assistance with their physical well-being are referred to the university health center.

If a student is uncertain about or needs to know more about his or her own capacities, interests, or personal characteristics, the university counseling service as well as testing services are available without charge. Confidential interviews may be arranged by any student who wishes to review his or her own progress and further evaluate or refine his or her thinking about future goals.

The university chaplain is available for the student with religious, moral, or personal concerns that are interfering with peace of mind and studies. A Roman Catholic chaplain also is in residence and available for counseling. A member of the faculty serves as adviser to Hillel Foundation members, who also may obtain spiritual advice from a local rabbi.

The Office of Career Services offers assistance to students in identifying and developing career options that can be initiated at

graduation. The office also manages an active on-campus interviewing program for graduating students.

The registrar assists students who have questions involving matters of transferred credits, graduation requirements, and allied topics.

The Office of Financial Aid consults with students who have financial concerns that are affecting their educational plans.

The Learning Center offers free individual tutoring in reading and study skills, mathematics, and writing.

Many members of the teaching faculty are also interested in students and student life. They serve as academic advisers, activity sponsors, group sponsors and advisers, and in friendly personal relationships with students.

In these and in other ways Lehigh University endeavors to maintain the close contacts with students that characterize the smaller institution. Services are available for all student concerns, and the student need only turn to his or her nearest residence hall counselor, professor, or the *Lehigh Handbook* to learn where help can be obtained.

## Health Center

The university offers health services to all students at the Health Center in Johnson Hall. Daytime hours during fall and spring semesters are 9:00 a.m. to 6:00 p.m. Monday through Friday, and 9:30 a.m. to noon Saturday. A registered nurse is available to see patients after hours, with a physician on call twenty-four hours daily. During vacation periods and summer, hours are 9:00 a.m. to noon and 1:00 p.m. to 4:30 p.m.

The Health Center staff treats a variety of health problems, including infectious illness and injuries. Routine gynecologic care is available by appointment. Allergy immunization prescribed by a student's allergist can be administered, as are vaccines for foreign-travel. No major surgery is performed at the Health Center. Most patients are seen on an outpatient basis, but facilities are available for inpatient care of students. When indicated, referrals are made to local medical or surgical specialists. Critically ill individuals are usually transferred to a general hospital.

Routine laboratory studies are done in the Health Center Monday through Friday from 9:00 a.m. to 5:00 p.m.

The health service includes a physical therapy department, supervised by a registered therapist who sees patients 8:30 a.m. to 4:30 p.m.

Prior to arrival to campus, each new or transfer student must submit to the Health Center a record of physical examination filled in and signed by a physician, and a completed health history form.

Following enrollment, additional examinations are provided by the Health Center for students participating in intercollegiate athletic programs, and when required for graduate school or scholarship programs. The Health Center does not provide examinations for military, insurance or employment purposes.

There is no charge for most of the care provided to students, whether inpatient or outpatient. Some exceptions are as follows: referrals to physicians, hospitals, or other medical facilities outside the student Health Center, and medications not carried by the Health Center and for which prescriptions need to be given. Staff, faculty, and other nonstudents are charged a fee-for-service.

A relatively low-cost university-sponsored insurance plan is available. Expenses covered include costs for several services that are not available at the Health Center, such as X-rays, certain laboratory studies, consultant fees, and medications not stocked by the Center. Hospital expenses are also covered. Students are urged to check with their parents regarding existing insurance coverage and to consider purchasing the university-sponsored plan if they are not adequately covered.

A health service brochure is distributed to all entering freshmen and is available through the Health Center to all other students. This brochure describes in more detail the policies and program of health service.

## Counseling Service

The Counseling Service, located on the fourth floor of Johnson Hall, offers students the opportunity for consultation with trained counselors and psychologists regarding a wide variety of personal and academic concerns. The service is dedicated to the belief that college years can be productive, rewarding, and satisfying ones during which students can grow in meaningful ways. All of the services provided are *confidential* and *free of charge*. To make an appointment it is simply necessary to call 758-3880, Monday through Friday. If questions arise whether a problem is best dealt with in the counseling center, inquiries are always appropriate and can be made anonymously.

Counseling/Psychotherapy may involve discussion and exploration related to *any* concerns, feelings or problems that students may have, ranging from those that arise during the course of normal development to more serious emotional problems. Most contacts will take place on an individual or small group basis. Staff psychologists are also available to present lectures, workshops, or seminars on psychologically related topics.

When a student consults with a therapist about a problem or concern the first step will be to determine the nature of the problem. This initial step of clarifying the concern can be very helpful and may be the only thing necessary to begin a resolution of the problem. An interview or psychological testing may be used during this assessment period. The counselor may also suggest different ways to handle the problem. A decision may be made to meet with the therapist for additional sessions to explore the difficulty in greater depth or to provide ongoing support during a tough time.

The most frequent types of concerns which students bring to counseling are:

**Anxiety/Stress**—When students are nervous, worried or experiencing attacks of acute anxiety their satisfaction and performance declines. Such feelings of stress may interfere with schoolwork, relationships, even sleep. Clarifying the source of the stress can help and there are different techniques that a counselor can offer to help students begin to feel and function better.

**Depression/Loss of Motivation/Low Self Esteem**—Each of these can effect how satisfied and productive one feels. They may be interconnected or related to other difficulties. Psychotherapy can be helpful in coming to understand the reason such feelings have become troubling, and can help the individual move toward some satisfactory personal resolution.

**Behavior Problems**—Problems of behavior are diverse and range from eating disorders, to loss of temper control, to chronic procrastination. The cause and treatment of each problem may be different but such problems have one thing in common, the loss of control over an important behavior. Working with a therapist, individually or in a small group setting, may involve a thorough analysis of the problem and the use of different techniques to aid in regaining behavior control.

**Interpersonal Problems**—These may involve problems getting along with a roommate, girlfriend/boyfriend, boss or family member. Often the break-up of a relationship, a divorce in the family, or the pressure of long-standing interpersonal conflicts can contribute to depression, anxiety and work problems. Talking with a therapist, either individually or in the context of a therapy group, helps to clarify the problem and the effect it may be having on other areas of functioning. Strategies can be identified to improve the situation and to cope better with the problem as it exists.

**Existential Concerns**—Not infrequently, students find themselves struggling with those difficult questions of who they are, what their lives are about, and how they can best live with integrity. Addressing some of these concerns in psychotherapy may allow greater freedom and involvement in the academic, personal, and social environment.

## The Learning Center

Success at Lehigh depends in part on mastery of a number of advanced academic skills. Such skills are needed to study effectively (prepare assignments, take notes, outline, listen, recall information), to take examinations, to write well, to understand advanced mathematical concepts, and to keep up with a great deal of critical and comprehensive reading.

At Lehigh, a campus noted for its highly motivated student body and strenuous academic program, 15 percent of undergraduates, including a third of full-time freshmen, use the tutorial services of The Learning Center. Established in 1977, it provides a schedule of

workshops, review sessions, and most importantly, individual tutorials in study skills, mathematics, reading and writing. Through a program of faculty and student referrals, along with periodic notices to the student body, the center helps students to improve specific communication and mathematical skills, to maintain acceptable performance levels, and to raise their academic standing. Individualized assistance is emphasized.

The Learning Center provides university students with a continuing opportunity for academic improvement through personalized instruction by professors and graduate teaching assistants. The center is located in the studio at the top of Coppee Hall.

## The Microcomputer Store

Lehigh's Microcomputer Store offers microcomputers, printers, software and accessories for Lehigh students, faculty and staff at reduced educational prices. The store is located at 524 Brodhead Ave. and is open weekdays from 9:00 a.m. to 5:00 p.m. Information regarding prices, special offers and other related details can be obtained through the campus network or by calling (215) 758-4606. Mastercard and Visa are accepted.

## Career Services

One function of a college education is to foster the growth and development of the student in preparation for a meaningful and satisfying life after college. Because developing one's career potentials an integral part of this process, Lehigh provides career planning and placement services for its students.

*Career planning* can best be described as an educational process through which students (1) identify and develop their abilities, aptitudes, and interests; (2) learn the relationship between their capabilities and interests, their university experiences, and professional opportunities outside the university; and (3) prepare for those opportunities.

*Placement* is the process of researching specific organizations that provide the types of work desired, interviewing for specific jobs through which career or professional interests can be satisfied, and then selecting from the options available the one that best meets students' needs. This part of the process also requires students to develop skills in such areas as writing effective resumes and cover letters, interviewing techniques, and individual job-search strategies to enhance productive interactions with employers.

The Office of Career Services offers the following resources and services to help students prepare for professional opportunities after graduation.

**Career resources.** Among the resources available in the Career Library are books and articles on career planning, current information on career opportunities, graduate school catalogs, job-search directories, a library of employer literature for approximately 700 companies, and a video-tape library covering a wide range of career-related subjects.

**Health professions advising.** The health professions advisor, along with a faculty advisory committee, provides information and guidance to candidates pursuing careers in medicine, dentistry, and other health professions, including individualized advising, special programs on health-related topics and field trips.

**Career programs and workshops.** The staff conducts a variety of seminars and presentations in collaboration with academic departments, professional societies, living groups, and other interested campus organizations. Workshops on resume writing, interviewing techniques, and job-search strategies are also offered.

**Summer jobs and LUCAN.** Summer and part-time job listings and internship opportunities are posted in Career Services and on the campus network for all students interested in gaining short-term, career-related experience. This is part of a new student employment initiative designed to offer "hands-on" career experience and financial assistance. The Lehigh University Career Advising Network (LUCAN) provides undergraduates with listings of specific summer job openings referred by Lehigh alumni.

**Individual consultation.** Students may meet with members of the staff to discuss their career options and goals, individual job-search strategies, effective interviewing, and related interests.

**Placement Manual.** This manual helps students learn how to use the on-campus interviewing system, prepare for interviews and plant/office visits, write resumes and letters, and develop individual strategies.

**On-campus interviewing.** Staff members work with approximately 800 business, industrial, and government representatives who interview on campus each year. Seniors and graduate students typically take a total of about 8,000 interviews.

The goals of this integrated career planning and placement process are for Lehigh students to think of themselves as educated people with skills and abilities that have value to employers, and to think in terms of functional responsibilities rather than merely linking their major subjects to jobs, to acquire and develop the skills necessary to become self-reliant and informed decision-makers, to prepare for a competitive job market, and to develop their potential of becoming self-reliant managers of their own careers.

The office, located in Christmas-Saucon Hall, is open throughout the year.

## Challenge For Success Program

The Challenge For Success Program (CFS) is a comprehensive supportive services program designed to enhance the recruitment and retention of the minority student community. Recruitment, retention, and relationships with industry are the primary components of the program.

The CFS program director works closely with the office of admission in the area of recruitment. Retention is enhanced by a six-week summer pre-freshman program, a student orientation, a peer counseling program, counseling for social and academic adjustment, a comprehensive tutorial service, and monitoring of academic progress.

The Black Alumni Council also assists in the retention effort. Relationships with industry include a mentor program, career awareness programs, summer employment, and a Corporate Advisory Board. The CFS Program is funded through gifts by corporate friends.

The CFS office is in the university center. In addition to the director, a graduate assistant, student assistants, and a staff of tutors and peer counselors are employed through the program. Tutorial services and the summer pre-freshman program are open to all students.

## Office of International Students and Scholars (OISS)

The purpose of this office is to serve the unique needs of foreign nationals who are students, scholars or faculty members at Lehigh University. More than 650 such "internationals" from over 60 countries currently enrich our community.

The OISS serves as a resource for those seeking advice, referrals or assistance on relevant international issues. It acts as a liaison to other offices and departments on campus, and to national and international agencies.

Our programs include orientation programs each semester for newcomers, programs for international spouses and children, multi-cultural events and workshops. The OISS is the sole source of information and referral on matters of immigration.

The OISS is located in Room 344, Whitaker Laboratory 5.

# III

## Academic Programs in the Colleges

*"My professors at Lehigh would not leave me alone until I got everything right."* – Lee Iacocca, Lehigh alumnus.

# III.

# Academic Programs in the Colleges

From its beginnings in 1865, the university's educational goal has been simple. As university president Dr. Peter Likins has observed, Lehigh affords "a liberal education for a useful life." Broadly, the university seeks to instill general life skills necessary to successful functioning in any career. These include:

- good oral and written communication skills;
- analytical and problem-solving abilities;
- interpersonal skills;
- "technological literacy"—the ability to integrate humanistic, social, and cultural values with technological utility.

This educational philosophy, supported by the three undergraduate colleges in the university, includes not only classroom offerings spanning the theoretical to the applied, but also extracurricular opportunities and support systems that enrich and reinforce intellectual and human growth.

Students are expected to take responsibility for their education, to seek out the varied educational opportunities at the university, and to use them fully. Help is available in each of the colleges, as well as through general university offices.

## Graduation Requirements

Students are expected to maintain regular progress toward the baccalaureate degree by carrying the "normal" course load—between fourteen and eighteen credit hours each semester. They may, however, wish to accelerate the pace toward graduation by using advanced placement credits, summer session study, course overloads during the regular semesters, and receiving credit for courses through examination.

Students in good academic standing earn their degrees by meeting the requirements of their specific degree curriculum as well as general university requirements. Waiver of program requirements is accomplished by a petition supported by the department and the committee on standing of students. Students should confer with their advisers on matters related to curriculum.

Students are expected to satisfy the credit-hour requirements of their chosen curriculum. Basic military science or aerospace studies credit hours are in addition to the credit hours specified in the curricula. A maximum of six credit hours of advanced military science and aerospace studies courses may be applied toward the baccalaureate degree.

## Advisement

Every undergraduate is assigned a faculty adviser. Until the major is declared, help is also available through the dean's office of the college in which the student is enrolled. When the major has been chosen, a faculty member from the major department will act as the academic adviser.

This adviser is one of the most valuable resources in the educational process, not only to assist in making academic selections to match the student's particular background, interests, and future objectives, but also to identify program options, to work out an academic pace, and to develop career planning strategies. The adviser will help to identify other resources and support systems available at the university, such as The Learning Center, the counseling service and the office of career services.

# Special Academic Opportunities

The academic programs in the colleges are supplemented by five-year, two-degree programs as well as opportunities for advanced, foreign, and experiential study.

## Five-Year, Two-Bachelor-Degree Programs

The university's five-year, two-degree programs enable a student to receive two bachelor degrees upon completion of five years of study.

The civil engineering and geological sciences program that affords two bachelor degrees, and the electrical engineering and engineering physics two-degree program are examples of programs in the College of Engineering and Applied Science.

Students who wish to declare a second major in another college or both a B.A. and a B.S. degree within the College of Arts and Science must have a minimum of thirty additional credit hours beyond the first degree credit-hour requirements in order to qualify for the second degree.

Most five-year, two-degree programs appear in the description of courses under Arts-Engineering and Five-Year Programs in Section V. It is possible to arrange for a dual bachelor degree program even after studying at Lehigh for some time. Engineering students, for example, who decide at any stage of study that they wish to meet the requirements for both the bachelor of arts and bachelor of science degree may complete the combined requirements in five years if the decision is made before the third year.

### *Arts-Engineering Option*

The curriculum in Arts-Engineering is especially designed for students wanting a regular professional education in a field of engineering and also the opportunity to study broadly in a second field.

Arts-engineers fulfill all requirements for the professional engineering degree for which they are working. However, the first three years of science and engineering courses are scheduled over four years for the arts-engineer. During this period the arts-engineer is a student in the College of Arts and Science pursuing a bachelor of arts or bachelor of science major program.

In normal circumstances the student will complete work for a degree in the College of Arts and Science at the end of four years. The

student transfers for the fifth year to the appropriate department of engineering, where he or she pursues a regular fourth year of science and engineering course work in the chosen field of engineering.

These arrangements make it difficult for an arts-engineer to qualify for the bachelor of science degree in the College of Engineering and Applied Science before meeting all requirements for the baccalaureate in the College of Arts and Science. In some instances it may be advisable to take the two degrees at the end of the fifth year. To qualify for both degrees, a student must submit for the second degree thirty credit hours in addition to the number required for the bachelor of science in engineering alone.

Arts-engineers working for the bachelor of arts automatically fulfill the engineering General Studies requirements of the College of Engineering and Applied Science while fulfilling the distribution requirements of the College of Arts and Science. Arts-engineers working towards the bachelor of science in biology, computer science, environmental science and resource management, geological sciences, geophysics, molecular biology, and statistics are advised to pay special attention to the engineering General Studies requirements, which must be met in time for the student to qualify for the B.S. in engineering.

Arts-engineers have the same opportunities for multiple majors and special interdisciplinary majors as are available to students working for the baccalaureate (B.S. or B.A. degree only) in the colleges.

# Bachelor/Master Degree Programs

Of increasing interest to undergraduates are the two-degree programs that may lead to both a bachelor and a master's degree in five years. Because Lehigh's well-established graduate programs are closely integrated with the undergraduate programs, it is possible to consider programs leading to the arts/master of business administration degree and the engineering/master of science in materials degree, among others. The fifth-year program in the School of Education enables those receiving a B.A. degree to accomplish professional teacher training and serve as salaried interns in public schools. After the completion of one year of full-time teaching, secondary teachers can receive the master of arts and elementary teachers can receive master of education degrees.

Many other five-year, graduate-level combination programs exist, and students are advised to consult with their adviser in planning such programs.

## *Arts/M.B.A. Program*

Students in the College of Arts and Science may enroll in a special arts/master of business administration program by completing the 43 credit hours of courses listed below in the suggested sequence, while completing their major in one of the B.A. programs in the college during their first four years. At the end of this period, if they are admitted to the Graduate School, they may be granted their M.B.A. degree upon completion of an additional 39 hours of course work. This can usually be accomplished in two regular semesters and two summer sessions.

All courses listed below under "other required courses" must have a grade of B minus or better in order to be credited toward the M.B.A. program.

The following comprise the required courses during the four years in the college:

required background courses

| | | |
|---|---|---|
| * | Eco 1 | Economics (4) |
| * | Math 41 | BMSS Calculus (3) **and** |
| * | Math 44 | BMSS Calculus II (3) **or** |
| * | Math 21 | Analytical Geometry & Calculus (4) **and** |
| * | Math 22 | Analytical Geometry and Calculus II (4) |
| * | Mgt 1 | Intro to Business Computing (3) |

other required courses

| | | |
|---|---|---|
| ** | Eco 145 | Statistical Methods (3) **or** |
| ** | Math 231 | Probability and Statistics (3) |
| ** | Acctg 51 | Essentials of Accounting (3) |
| ** | Acctg 52 | Essentials of Accounting (3) |
| ** | Eco 105 | Microeconomic Analysis (3) |
| ** | Eco 119 | Macroeconomic Analysis (3) |
| *** | Acctg 324 | Cost Accounting (3) |
| *** | Mgt 269 | Management in Operations in Organizations (3) |
| *** | Mgt 302 | Quantitative Models—Conceptual (3) |
| *** | Law 201 | Legal Environment of Business (3) |
| *** | Eco 229 | Money and Banking (3) |

* recommended in the freshman year
** recommended in the sophomore year
*** junior standing required for this course

Note: Students who do not take Acctg 52 and Acctg 324 as undergraduates will be required to take Acctg 413 as part of their M.B.A. course work.

# Interdisciplinary Programs

The university's interdisciplinary programs are designed to cross the boundaries between colleges to accommodate new and developing fields as well as the interests of students. They include such programs as the following:

**Afro-American Studies.** A number of courses relevant to Afro-American Studies are available, such as: Engl 319, The Black in American Literature; Govt 352, Civil Rights; and Hist 131, The Black Experience in America; SR 368. Students interested in work in Afro-American Studies may work out an interdisciplinary program with their advisers and college deans.

**Law and Legal Institutions.** This minor program involves eighteen credit hours of course work in the College of Arts and Science and the College of Business and Economics and is available to students enrolled in all three colleges.

**Freshman Seminars.** Interdisciplinary, problem-centered, three-credit-hour seminars for freshmen enrolled in all curricula are called Freshman Seminars. These serve as a General Studies option in the engineering and physical sciences curriculum, a preliminary distribution elective in the arts and science curriculum, and an arts option or free elective in the business and economics curriculum.

**Science, Technology and Society Program (STS).** Faculty from all three colleges explore the interrelationships between science and technological advancement and the quality of human life in the popular STS program.

**Interdisciplinary Technology Courses.** Several courses have been developed to make students better aware of an understanding of the role that science and technology play in society. They are intended primarily for non-science and non-technology students, but science and engineering majors may also take them. None of these courses may be used to satisfy distribution or general studies requirements. These courses are taught by faculty from the College of Arts and Science and the College of Engineering and Applied Science. Course numbers may vary by semester; consult STS Program or College Dean's offices for specific details.

# Experiential Learning

The accommodation of student interest extends beyond regular departmental offerings. Hands-on experiences in learning enrich classroom instruction. Each of the three colleges offers a number of such experiences to undergraduates. Among them:

**The Philadelphia Urban Semester.** Undergraduates in all fields of study can earn 16 Lehigh credit hours by spending a semester studying in the nation's fourth-largest metropolis. They live, work, and study with other students from two dozen other institutions, supervised by faculty of the Great Lakes Colleges Association. This consortium of such leading Midwestern institutions as DePauw, Kenyon, Oberlin, and Wooster is a recognized leader in providing extra-mural academic programs both here and abroad.

The curriculum consists of two four-credit seminars and an eight-credit internship. All students are enrolled in a core "Seminar on the City" which introduces them to the field of urban affairs and to Philadelphia. The second seminar is elected from a half-dozen more specialized urban topics; recent choices available have included "Folklore in Philadelphia," "Art in the City" (which met each week at a different site), and "Justice." Internships involve working four

days weekly in a public or private placement which tests the student's aptitude in a variety of practical ways while enhancing appreciation of city life.

**The Washington Semester.** Opportunity is available each year for six juniors or seniors to spend a term studying in Washington, D.C., in cooperation with American University. Lehigh University is a member with 180 other colleges and universities.

Students enroll at Lehigh but spend the semester in residence at American University with the students from other participating colleges.

The curriculum consists of national-government seminars, an internship, and a written research project. Besides the national government program, the student may choose other program offerings such as economic policy semester, journalism, public administration, foreign policy semester and justice semester.

**Study in foreign countries.** Study abroad is increasingly recognized as a valuable component of undergraduate and, in some cases, graduate programs. Students maintaining a B average (3.0 cumulative) or better are encouraged to consider enrolling in an approved program for study abroad.

In some cases, study programs may include professional internships with foreign firms or organizations. Such internships must be approved by the Committee on Study Abroad before the student begins the internship. The internship will be monitored for its academic value.

All study abroad programs, conducted under the auspices of Lehigh University or another university, must be approved by the Committee on Educational Policy's Standing Committee on Study Abroad.

A Lehigh student who wishes to study abroad under the auspices of any non-Lehigh program and who wishes to have the academic work taken in that program count toward a Lehigh degree must have a GPA of at least 2.7. Any student with a lower GPA may appeal to the Committee on Study Abroad for an exception to this rule before leaving to study abroad.

Before any student or students can enroll, they must clear their study plans in advance with the departments concerned, the major advisor, the Registrar and Dr. Karen Keim, Study Abroad Coordinator, 216 Maginnes Hall. Students desirous of applying their financial aid to study abroad must consult with the office of financial aid prior to their departure. For foreign-language students, the approval of the adviser for the foreign language concerned is required.

Through the department of modern foreign languages and literature, the university offers scholarships for qualified students, on a competitive basis, to assist with travel costs for foreign-language programs.

As a member of the Lehigh Valley Association of Independent Colleges (LVAIC), Lehigh University sponsors three six-week summer programs in Europe: Poitiers, France; Bonn, Federal Republic of Germany; Seville, Spain. The six credits earned are automatically transferable to Lehigh University and will be counted as part of the student's cumulative grade-point average.

The Center for International Studies, Maginnes Hall, coordinates foreign study and internship applications and maintains listings of current programs. Students are encouraged to inform the center of their interest in foreign study or internship by completing an application form at the end of their freshman year or early in their sophomore year to allow adequate planning time.

The Lehigh Valley Center for Jewish Studies sponsors summer, semester and year study programs in Israel in cooperation with Tel Aviv University and the Hebrew University in Jerusalem. During the summer students may also participate in the Tel Miqne-Ekron Archaeological Excavations as well as a kibbutz study program. Limited scholarships are available from the Lehigh Valley Center for Jewish Studies for qualified students on a competitive basis.

**The Exchange Program with British Universities.** Lehigh University has formal exchange agreements with seven British universities. Students selected for the program can study at the University of Buckingham for a semester or at the following universities for a year: University of Edinburgh, University of Kent, London School of Economics and Political Science, University of Manchester Institute of Science and Technology, University College of London University, and University of York.

In this program, courses and grades are transferred and transcripted to Lehigh. Tuition is paid to Lehigh and financial aid continues. Students are responsible for board and lodging at rates comparable to those of Lehigh. Travel scholarships are available.

Applications are available through the dean's office in each college. Generally a 3.0 grade-point average is required. Students must obtain their adviser's approval and the endorsement of their college. All applicants are interviewed by the committee for study abroad, which selects candidates for the available positions.

**Inspection trips.** The location of the university in the center of industrial activities of various types affords unusual opportunities for visits to manufacturing plants. Inspection trips to individual plants are a required part of specific courses in various engineering curricula. Written reports may be required. These trips are generally held during the senior year and involve an average expense of $25 to $50.

## Preparation for Graduate Work

Students planning to continue in graduate programs should take advantage of the flexibility in many undergraduate programs to design an upper-division curriculum that meets requirements in the anticipated graduate program.

The policy of the Graduate School provides as much flexibility as possible for students who wish to change to new but related fields of study after the baccalaureate degree. Students should consult with their previous program adviser and the department representative of the new field to establish an academic program that will remedy any deficiencies in background.

## Curricular Flexibility

Choice is a regular part of university life, and encompasses the determination of a college and major, the selection of courses each term, and the development of life goals and career options.

Many of these choices are academic in nature. The undergraduate curricula are flexible, designed to accommodate the changing interests and needs of students. Boundaries between colleges are as fluid as possible to provide many options in an educational program. For instance, students may take a bachelor of science (B.S.) degree in the College of Business and Economics or the College of Engineering and Applied Science with a minor in journalism in the College of Arts and Science. There are five-year programs for which degrees are awarded in two colleges.

Transfers between undergraduate colleges is permitted but only *after the freshman year.* Students considering such a transfer must confer with their advisers to begin the process.

Academic offerings of the various departments are described in Section V. To provide additional flexibility and encourage student initiative and depth of investigation, the university has developed academic alternatives including the following:

**Provisional Courses.** Departments may introduce Provisional Courses temporarily within a semester, either experimentally or as a response to a contemporary social or scientific issue. If successful, a course may become part of the regular curriculum. Such courses, identified with a 97 or 98 number (preceded by a 1, 2, or 3 indicating level) may sometimes be taken on a pass/fail basis. They may not be developed in time to be included with course listings but they are incorporated into the registrar's semester roster for a maximum of two semesters.

**Independent Study.** Juniors and seniors of ability who wish to concentrate in their chosen field can substitute no more than four or six credit hours of independent, unscheduled work each semester for an equal number of credit hours of elective work required for graduation. Students, in collaboration with the major adviser, with the advice of the departmental chairperson and consent of the college dean, may structure such a project for study in any curriculum and most major study sequences.

**Pass/Fail Option.** Students have the opportunity to study in areas without concern for possible poor grades by electing a pass/fail option. Intended for exploration outside the major field, this option is open to those who are sophomores and above, in good standing, who have declared a major. The pass/fail option may not be used for major or minor subject credit toward graduation. Consultation with the adviser is suggested.

**Graduate Courses.** Qualified undergraduates may petition the

Graduate Committee to register for 400-level courses if they are certified by the course instructor and the department chairperson concerned.

**Cooperative College Program.** Students can attend courses and programs offered by the member institutions of the Lehigh Valley Association of Independent Colleges (LVAIC). The other institutions are Allentown College of St. Francis de Sales, Cedar Crest College, Lafayette College, Moravian College, and Muhlenberg College. Consult the registrar for details.

**Summer Study.** Remedial and advanced academic work can be taken in two summer sessions. Special programs and field work opportunities are available for intense in-depth experience. There are also short courses in a variety of subjects. A listing of planned summer programs is available in the spring.

## Honors Opportunities

Each department offers honors work adapted to its curriculum for students who wish to demonstrate unusual academic ability and interest in exploring a chosen field through independent study and research. The precise nature of the program for each student is determined by the academic major department, but may include: unscheduled work or independent study; participation in graduate (400-level) courses; and an honors thesis or project.

Qualified candidates should inform their academic advisers by the end of the junior year of their intention to work for departmental honors. The adviser will give the college and the registrar names of seniors working for departmental honors in particular majors. Names of those students attaining departmental honors are published in the commencement program.

Undergraduates in the College of Arts and Science may apply for acceptance into the College Scholar Program, which offers unique opportunities for those qualified to develop their critical faculties and intellectual interests.

# College of Arts and Science

James D. Gunton, *dean;* G. Mark Ellis, *associate dean;* Judith N. Lasker, *associate dean*

The College of Arts and Science offers several curricular options:
- A four-year curriculum in arts and science, leading to the degree of *bachelor of arts*;
- Four-year curricula in the fields of biology, computer science, environmental sciences and resource management, geological sciences, geophysics, molecular biology, and statistics, leading to the degree of *bachelor of science* in the designated field; and
- A *five-year curriculum* in arts-engineering leading to a bachelor's degree from the College of Arts and Science and a bachelor of science degree in the student's field from the College of Engineering and Applied Science.

Students in all of these curricula must complete Arts and Science 1, Choices and Decisions, and meet a requirement for freshman English. The normal requirement is Engl 1 and 2, 4, 6, 8 or 10. See Advanced Placement in Section II.

Specific requirements for many of the degree programs described in this section may be found in Section V.

## Major Subjects

The college offers the following major subjects:

### *Bachelor of Arts Degree*

**Humanities:** architecture; art; classics—classics and classical civilization; English; journalism; modern foreign languages—French, German and Spanish; music; philosophy; religion studies; theatre.

**Social Sciences:** American studies; cognitive science; economics; government; history; international careers; international relations; journalism and science writing; science, technology and society studies; social relations (includes anthropology, social psychology, and sociology); urban studies.

**Mathematics and Natural Science:** applied science; biology; chemistry; computer science; geology; mathematics; natural science; physics; predental science; premedical science; psychology.

### *Bachelor of Science Degree*

**Natural Sciences:** behavioral and neural biology; biochemistry; biology; chemistry; computer science; environmental sciences and resource management; geological science; geophysics; molecular biology; physics; statistics.

(Note: On July 1, 1987, the departments of chemistry and physics moved from the engineering college to the College of Arts and Science, where they joined the other science departments. Because the change is primarily related to the university's organization, students enrolled in chemistry and physics programs will not be significantly affected in their course work.)

### *Major Field of Concentration*

By the end of the sophomore year, each student in the curriculum of arts and science selects some sequence of studies as a major field of concentration. A major consists of at least fifteen hours of advanced work in the field chosen. Including preliminary college work, the minimum number of hours constituting a major is 30.

The major field of concentration is designed to enable a student to master an area of knowledge so far as that is possible during the undergraduate years. In all fields, certain courses are prescribed, but merely passing courses will not satisfy the major requirements. A student must achieve a minimum 2.0 average in major courses.

**Standard major sequences.** The student may choose one of the standard major sequences. When a student selects one of these standard majors, the chairperson of the department offering the major or the director of a nondepartmental major becomes a student's major adviser and makes out the student's major program. The final responsibility for meeting both major and nonmajor requirements, however, rests with the student.

**Special interdisciplinary majors.** In addition to the standard major programs, specially structured interdisciplinary major sequences are possible.

For example, a student interested in a professional school of urban or regional planning might wish to structure a special major consisting primarily of courses in government and economics, or in economics and social relations.

Any student may, with the aid of faculty members chosen from the disciplines involved, work out an interdisciplinary major program to include not less than thirty hours of related course work, of which at least fifteen hours shall consist of advanced courses. The program must be approved by the major advisers and the dean of the college.

**Multiple majors.** Some students choose to fulfill the requirements of more than one major sequence. A student initiates this by having separate major programs made out by different major advisers.

Because successful completion of only one major program is required for a baccalaureate degree, a student with more than one program is asked to designate one as the administrative major for preregistration purposes but is expected to maintain normal progress in fulfilling the requirements in both.

Students who wish to declare a second major in another college or both a B.A. and B.S. degree within the college must have a minimum of thirty additional credit hours beyond the first degree credit-hour requirements in order to qualify for the second degree.

## Junior-Year Writing Certification

The faculty of the College of Arts and Science is committed to the concept that writing is a valuable tool for learning and views the ability to write well as a valuable professional skill. Students are encouraged to take courses that require writing throughout their years in the college.

Beginning with the Class of 1988, each student in the college must

complete at least one "writing-intensive" course and receive writing certification from the instructor. Students normally take this course during the junior year. Students must follow the guidelines for this requirement set up by their major departments. Some departments specify that the "writing-intensive" course must be in the major field; some departments require "writing-intensive" courses in specified disciplines other than the major; and, other departments allow their majors to choose freely from "writing-intensive" courses across the college. Courses that satisfy the junior-year writing requirement may also satisfy major or distribution requirements.

# Bachelor of Arts Degree

The curriculum in arts and science emphasizes a liberal education. It asks the student, in collaboration with the adviser, to select courses to satisfy three general categories, namely, distribution to insure breadth of education, a major field of concentration to provide depth, and free electives to provide breadth and depth to meet the student's needs.

## *Distribution Requirements*

There are three categories of requirements: a *College requirement* (Arts and Science 1, Choices and Decisions) designed to acquaint freshmen with the approach to a liberal education; a *General Skills* requirement, to be completed by the end of the sophomore year, ensuring minimum competency in English, a foreign language, and mathematics; and the *Distribution* requirement (to be completed by the end of the junior year), which obliges all bachelor of arts students, whatever their major, to take a minimum number of courses in five subject areas which are essential for a liberal-arts education.

I. **College Requirement** (to be completed by the end of the freshman year), one hour total

A&S 1, Choices and Decisions — 1 credit hour

II. **General Skills Requirement** (to be completed by the end of the sophomore year), 18-22 hours total

A. *English composition* (two courses during the freshman year) — 6 hours

B. *Foreign language* (completion of, or credit for, second year level in any modern or classical language studied in high school; or two semesters at the elementary level of languages not offered for admission). — 6-8 hours

C. *Mathematical Sciences* (two courses) — 6-8 hours
Two courses from among mathematics, computer programming, logical theory (Philosophy 14 and 214 are acceptable), of which at least one must be a mathematics course.

III. **Distribution Requirement** (to be completed by the end of the junior year), total: 36-42 hours

At least one of the courses in Physical of Life Sciences must also include the associated laboratory course. Courses taken within the major department to satisfy a major may not satisfy distribution requirements in more than one area.

A. *Physical Sciences* — 6-10 hours
Two courses from among those designated in:
astronomy, chemistry, geological sciences, physics.

B. *Life Sciences* — 3-4 hours
One course from among those designated in:
biological anthropology, biology, and psychology.

C. *Social Sciences* — 12-13 hours
Four courses from among those designated in:
anthropology, economics, government, history, international relations, journalism, psychology, social psychology, sociology, STS, and urban studies.

D. *Humanities* — 12 hours
Four courses from among those designated in:
classics, history, history of architecture, history of art, history of music, history of psychology, history of theater, journalism, literature, cultural studies, music theory, philosophy, and religion studies.

E. *Performing and Studio Arts* — 3 hours
One course from among those designated in:
architectural design, creative writing, journalism, speech, theater, studio arts, music composition and performance.

Total required for graduation: 121 hours

A student's program, including the choice of distribution requirements, is not official until approved by the adviser.

## *Graduation Requirements*

The bachelor of arts degree (B.A.) requires the completion of a minimum of 121 credit hours of collegiate work, apportioned to cover distribution and concentration requirements. A cumulative average of 2.0 or better in courses required in the student's major program and the completion of all general requirements apply to all candidates for baccalaureate degrees. Candidates must complete Arts and Science 1, and must receive writing certification in the junior year. A maximum of six credit hours of advanced military science or aerospace studies courses may be applied toward the degree.

# Bachelor of Science Degree

Students desiring to major in the fields of biology, biochemistry, chemistry, computer science, environmental sciences and resource management, geological sciences, geophysics, molecular biology, physics, and statistics may elect to work for a bachelor of science degree (B.S.). This option is also open to arts-engineers desiring to major in one of these fields.

A student electing to work for the bachelor of science degree may have a strong preprofessional orientation and will take more courses in the major field of concentration than will another in the bachelor of arts (B.A.) program. In all other respects the student in a bachelor of science curriculum meets the same requirements as the student in the bachelor of arts program, except that the B.S. candidate is not asked to fulfill the same distribution requirements.

The bachelor of science distribution requirements in the College of Arts and Science consist of a minimum of thirty credit hours taken in courses outside the natural sciences and mathematics. Of these thirty credit hours, at least twelve credit hours must be taken in courses in the humanities, and at least twelve in the social sciences. The humanities and social science courses satisfying this distribution requirement are those approved by the faculty for this purpose and listed under the appropriate categories of the distribution requirements for the B.A. degree.

## *Graduation Requirements*

The bachelor of science degree requires the completion of the minimum number of credit hours of collegiate work indicated for the curriculum, including the 30-credit-hour B.S. distribution requirement. Candidates must complete all general requirements for the baccalaureate degree, including completion of Arts and Science 1 and completion of junior-year writing certification. A maximum of six credit hours of advanced military science or aerospace studies courses may be applied toward the degree.

# Language Requirements

Students who are planning on graduate study toward the doctor of philosophy degree are reminded that most graduate schools require Ph.D. candidates to demonstrate a reading knowledge of one or two foreign languages. Ability to use foreign languages is beneficial in many careers, such as law, journalism, commerce, industry, and government.

# Centers and Institutes

The college participates in research and scholarship in a number of

centers and institutes, where graduate and undergraduate students work closely with faculty members. These include: Center for Advanced Technology for Large Structural Systems, Center for International Studies, Center for Molecular Bioscience and Biotechnology, Center for the Application of Mathematics, Environmental Studies Center, Health Sciences Institute, Center for Innovation Management Studies, Center for Social Research, Emulsion Polymers Institute, Energy Research Center, Institute for Bioengineering and Mathematical Biology, Institute for the Study of the High-Rise Habitat, Lawrence Henry Gipson Institute for Eighteenth-Century Studies, Lehigh Valley Center for Jewish Studies, Materials Research Center, Sherman Fairchild Center for Solid-State Studies, The Stone Harbor Marine Laboratory, Technology Studies Resource Center, Zettlemoyer Center for Surface Studies.

# Minor Programs in the College

Certain departments, divisions, and programs in the College of Arts and Science afford an opportunity to minor in an additional field of concentration other than the major field.

A minor consists of at least fifteen credit hours; the specific content is determined in the department, division, or program concerned. A minor is optional and, if successfully completed, will be shown on the university transcript in the same manner as the major field of concentration. A 2.0 minimum grade-point average is required for courses in the minor. Because of this requirement, no course in the minor program may be taken with Pass/Fail grading.

If a minor program is not listed under the department desired, the student should consult the department chairperson.

It is the responsibility of students desiring a minor to initiate it no later than the beginning of the junior year by filing a minor program with the department, division, or program where it is offered. The student's major adviser keeps appropriate records.

Minors in the College of Arts and Science departments and programs are available for degree candidates in other colleges within the university, with approval of their college adviser.

## *Education Minor*

The education minor helps undergraduates explore a career option in school teaching or other professional careers with elementary, secondary, or special-education students. The minor may accelerate entry into a teaching career because appropriate credits from the minor may be applied toward completion of teacher-certification credits for those admitted to Lehigh's graduate-level Teacher Intern Program.

The minor offers a systematic background of professional education experiences, coordinating practicum activities with theory courses designed to provide a foundation for future educational studies. Its focus is exploratory. No career decision is required but the minor is provided for those with a serious interest in considering the teaching profession.

The experiences of the minor are intended to enrich an individual's understanding of education as a central intellectual phenomenon of our culture and to provide self-understanding of one's own potential as an educator.

An undergraduate may take one or all of these courses during the junior and senior years with the approval of the adviser. Completion of the minor does not assure admission to the Teacher Intern Program to become a certified professional. However, if the student passes the screening process on the basis of previous work and interviews, he or she may enter the intern program with advanced standing toward certification.

The program coordinator is Robert L. Leight, Mountaintop Campus, 111 Research Drive.

Fifteen credit hours are chosen from among the following courses for those in the education minor:

| | |
|---|---|
| Educ 312 | Classroom Practice (1) (must be taken concurrently with Educ 314) |
| Educ 314 | Intern Seminar (2) (must be taken concurrently with Educ 312) |
| Educ 429 | Child Development (3) |
| Educ 441 | Youth in Society (3) |
| Educ 394 | Special Topics in Instruction and Curriculum (3) |
| Elective | Education course (appropriate to student's objective (3) |

## *East Asian studies*

The minor program in East Asian studies affords undergraduates in any college within Lehigh an opportunity to acquire a systematic knowledge of East Asia (China, Japan, Korea and the Pacific). The program encompasses the rich historical and cultural heritage of the countries of East Asia, as well as their growing importance in world affairs and their critical relationship to the national interests of the United States.

The minor is intended as a complement to a student's major field of study, and it is flexible according to individual needs. Students are free to survey the field broadly or concentrate in a special area such as the Chinese language. The minor is composed of any five courses (15 credits minimum) in East Asian studies, chosen from an approved list in consultation with the program director. Courses in Japanese language and related East Asian topics are offered at Lafayette College and other LVAIC institutions and may be taken for credit by Lehigh students. In addition, students are encouraged to avail themselves of a variety of extracurricular activities that are offered in East Asian studies, such as special lectures and seminars, films, performances and exhibits.

The over-all program is administered by the East Asian Studies Committee, an interdisciplinary body of faculty members with a special interest in the region. This committee oversees both the formal academic work within the program as well as the extracurricular activities sponsored at the university. It also cooperates with the East Asia Society, the Chinese Students Club, and other campus organizations involved in some aspect of East Asian studies.

The following courses are regularly offered in the program and new ones are currently under development in a number of other fields. It is expected that a major program in East Asian studies will be introduced shortly in cooperation with the Lehigh Valley Association of Independent Colleges. The director is Raymond F. Wylie, Maginnes Hall.

*East Asian Studies Courses*

| | |
|---|---|
| Anth 184 | Cultures of the Pacific (3) |
| Chin 1 | Elementary Chinese I (4) |
| Chin 2 | Elementary Chinese II (4) |
| Chin 11 | Intermediate Chinese I (3) |
| Chin 12 | Intermediate Chinese II (3) |
| IR 21 | East Asia to 1945 (3) |
| IR 22 | Contemporary East Asia (3) |
| IR 321 | China in World Affairs (3) |
| IR 323 | Japan in World Affairs (3) |
| MFL 71 | Introduction to Chinese Culture (3) |
| Rel 115 | Religions of China (3) |
| Rel 117 | Religions of Japan (3) |
| Rel 226 | Topics in Asian Religions (3) |
| STS 141 | Science and Technology in East Asia (3) |

## *Health and Human Development Minor*

The minor in health and human development, located primarily within the College of Arts and Science, is an interdisciplinary program designed to provide insight into the social/scientific aspects of health issues through the human life cycle. While this minor program is open to anyone in the three undergraduate colleges, it may be of particular interest to students preparing for careers in medicine, dentistry, optometry, allied health professions, health administration, social work, and child or adult development.

The program is administered through the Program in Health and Human Development, an interdisciplinary group of faculty members who have research interests in this area. Current research studies cover all aspects of the life cycle, including the health dimensions of both normal and abnormal child development, reproductive health issues, adult life crises such as illness and loss, and dimensions of

aging. Students are able to serve as research assistants in some of these studies. The program also sponsors a series of lectures and colloquia. Students in the minor program are encouraged to avail themselves of these opportunities.

The minor consists of a minimum of fifteen credit hours chosen in consultation with the program director, Nancy Fulford, health professions coordinator, Maginnes Hall. Students may decide to survey the field broadly or to concentrate in the area of health or human development.

*required courses* (6 credit hours)

| | |
|---|---|
| Hist 8 | History of Medicine in America (3) **or** |
| Soc 135 | Medicine and Society (3) |
| **and** | |
| Psych 107 | Child Development (3) **or** |
| Psych 108 | Adolescent Development (3) **or** |
| Psyc/SPsy 109 | Adult Development and Aging (3) |

*elective courses* (9 credit hours) chosen from three different disciplines:

| | |
|---|---|
| Anth 321 | Anthropology of Physical and Mental Health (3) |
| Govt 306 | Public Policy Process (3) |
| Hist 8 | History of Medicine in America (3) |
| Hist 337 | History of Medical Thought (3) |
| Hist 339 | Topics in American Public Health (3) |
| Hist 340 | Topics in American Medicine (3) |
| Phil 116 | Medical Ethics (3) |
| Psyc 77 | Drugs and Behavior (3) |
| Psyc 107 | Child Development (3) |
| Psyc 108 | Adolescent Development (3) |
| Psyc 109 | Adulthood and Aging: Social and Psychological Perspectives (3) |
| Psyc 305 | Abnormal Psychology (3) |
| Psyc 351 | Cognitive Development in Childhood (3) |
| Psyc 361 | Special Topics in Adult Development (3) |
| Psyc 363 | Social and Personality Development (3) |
| SPsy 109 | Adulthood and Aging: Social and Psychological Perspectives (3) |
| SPsy 321 | Social Psychology of Developing Adults (3) |
| Soc 135 | Medicine and Society (3) |
| Soc 327 | Health Policy Analysis (3) |
| Soc 333 | Sociology of Aging (3) |
| Soc 341 | Women and Health (3) |
| SR 331 | Social Perspectives on Death and Dying (3) |

## *Interpersonal Behavior in Small groups And Organizations*

This minor has as its general focus the understanding of face-to-face interaction among human beings in small-group settings in a variety of organizational contexts. It will be relevant to students interested in personnel, the helping professions, group work, or any occupation requiring interpersonal skills in group settings.

The minor has both a cognitive and experiential learning dimension. Thus the student may become acquainted with the major theories, concepts, and issues concerning interpersonal behavior in social contexts and also with some of the tools, skills, and insights that promote growth and competence in social interaction. Experiential learning also includes training in techniques of naturalistic observation of social interaction in small groups and organizations.

These courses are not arranged in a sequence; that is, while they individually may put more stress on the cognitive or experiential dimension, none are prerequisites for any other. Thus students may select any course, subject to the prerequisites and requirements of the university and the department, as well as availability.

The coordinator is Robert E. Rosenwein, Price Hall.

Fifteen credit hours are chosen from among the following courses for the minor in Interpersonal Behavior:

| | |
|---|---|
| Mgt 321 | Organizational Behavior (laboratory sections only) (3)* |
| Psyc 121 | Encountering Self and Others (3) |
| SR 118 | Close Personal Relationships (3) |
| SPsy 121 | Social Psychology of Small Groups (3) |
| Anth 151 | Utopias and Alternative Communities (3) |
| SR 395 | Methods in Observation (3) |
| SPsy 312 | Interpersonal Behavior in Small Groups (3) |

## *Jewish Studies*

The Jewish Studies minor offers students of diverse backgrounds the opportunity to explore the history, literature, religion and social institutions of the Jewish people from its inception to the present. The diversity of courses highlights the interaction of Judaism with other world civilizations and the mutual influences between Judaism and societies and cultures of Europe, the Middle East, and the United States. Through the Jewish Studies minor, a student has the opportunity to study Judaism from the perspective of various academic disciplines.

The program is designed to be of interest to students with diverse interests and fields of concentration. The study of Jewish society and culture can enhance one's understanding of European or American society and culture. Students of psychology and sociology will find that Jewish Studies contributes to their understanding of such issues as prejudice and anti-Semitism, assimilation, and religious-cultural pluralism.

The study of Jewish religion and philosophy brings one face to face with such problems as God, religious faith and doubt, moral responsibility, evil and human suffering. In addition, studying Judaism in comparison with another religious tradition heightens one's understanding of both religions. The study of Judaism introduces the student of literature to a broad sample of diverse literary forms and themes from diverse periods and cultural settings.

The formal program of courses is augmented through a program of lectures, colloquia, films, and other cultural exhibits. Study abroad, particularly in Israel, is encouraged as a means to augment and broaden one's understanding of Jewish civilization. Under the sponsorship of the Lehigh Valley Center for Jewish Studies, students may study for a semester or a year at the Hebrew University in Jerusalem or Tel Aviv University. During the summer, students may earn up to six credit hours by participating in the Hebrew University summer study program in Jerusalem, the kibbutz-study program of the Hebrew University, or the Tel Miqne-Ekron archaeological excavation. For further information on programs in Israel, students should contact Myra Rosenhaus. Students should coordinate their minor program in Jewish Studies with the director of the center, Laurence J. Silberstein, Maginnes Hall.

A minimum of fifteen credit hours is to be selected from the following courses. (A maximum of six credit hours of Hebrew may be counted.) In addition to the following courses, which are offered regularly, new courses are offered annually. Students should check with the Jewish Studies office, Maginnes 321, for an updated list.

**Jewish Studies Courses**

| | |
|---|---|
| Engl 312 | Jewish Literature (3) |
| US 328 | The American Jewish Community (3) |
| Hebr 1 | Elementary Modern Hebrew I (3) |
| Hebr 2 | Elementary Modern Hebrew II (3) |
| Hebr 11 | Intermediate Modern Hebrew I (3) |
| Hebr 12 | Intermediate Modern Hebrew II (3) |
| IR 31 | Middle East in World Affairs to 1943 (3) |
| IR 32 | Middle East in World Affairs Since 1945 (3) |
| MFL 61 | Cultural Mosaic of Modern Israel (3) |
| Phil 133 | Medieval Philosophy (3) |
| Rel 73 | Introduction to Judaism (3) |
| Rel 108 | Modern Judaism (3) |
| Rel 111 | The Hebrew Bible/Old Testament (3) |
| Rel 116 | Zionism and the Renewal of Judaism (3) |
| Rel 127 | Sex and Gender in Judaism: The Feminist Critique |
| Rel 141 | Literature of the Holocaust (3) |
| Rel 145 | Jewish Thought Since the Holocaust (3) |
| Rel 151 | The Jewish-Christian Encounter (3) |
| RS/Hist 154 | The Holocaust: History and Meaning (3) |

| | |
|---|---|
| Rel 163 | Contemporary Theology (3) |
| Rel 244 | Major Figures in Modern Jewish Thought (3) |
| Rel 257 | Jewish Thought Since the Enlightenment (1750 to Present) (3) |
| Rel 371 | Special Topics (1-3) |

## *Latin American Studies*

The minor in Latin American Studies represents an opportunity to explore the language, literature, history, cultures, and socioeconomic problems of our neighbors to the south. It provides a perspective on the problems of other underdeveloped regions of the world, in contrast to most offerings in the humanities and social sciences that usually focus on the mainstream of western culture, notably the United States and Western Europe.

It is worth noting the importance of Latin American cultures in the future of the hemisphere. Latin America is the most rapidly growing part of the world, and by the year 2000 it is predicted that the area will have a population of 600 million, or twice that of Anglo-America. Several countries, especially Brazil and Mexico, are undergoing rapid industrial expansion. Consequently, besides the personal values to be derived from this curriculum, there are business, governmental, and related career possibilities.

The minor program represents fifteen credit hours, or five courses, chosen from economics, history, sociology and Spanish, in discussion with the coordinator, James S. Saeger, history department, Maginnes Hall.

*Required course* (3 hours)

| | |
|---|---|
| Span 152 | Cultural Evolution of Latin America (3) |

*Elective courses* (12 hours) chosen from:

| | |
|---|---|
| MFL 81 | Brazil and its Culture (3) |
| Eco 305 | The Economic Development of Latin America (3) |
| Hist 49-50 | History of Latin America (3) |
| Hist 265 | Mexico and the Caribbean (3) |
| Hist 266 | Argentina, Brazil and Chile (3) |
| Hist 368 | Seminar in Latin American History (3) |

courses in Latin American literature, government or international relations (6)

No more than six credit hours should be chosen from a given department. A proficiency level in Spanish and/or Portuguese is required, depending on the student's area of special interest.

## *Law and Legal Institutions*

This program, based in the College of Arts and Science, is designed to foster interdisciplinary cooperation with the faculties of the other colleges in the university. The Law and Legal Institutions minor program is open to students from all three undergraduate colleges. Although the program may be of particular interest to some pre-law students, it should not be viewed as the preferred pattern for those hoping to attend law school.

The eighteen-credit-hour program stresses the systematic analysis of contemporary legal institutions, coupled with an examination of their historical antecedents, especially those in the Anglo-American common-law tradition. The program also exposes students to both public and private law, and to courses using the traditional case methods as well as those of the social sciences and philosophy.

Each student's minor program is a coherent combination of courses individually and jointly designed by the student and the program director. To avoid unnecessary confusion, students are urged to declare their minor in Law and Legal Institutions by the end of their sophomore year, in no event later than the last semester of their junior year.

*Required preliminary courses* (6 credit hours)

| | |
|---|---|
| Phil 13 | Practical Logic (3) |
| Law 11 | Introduction to Law (3) |

*Elective courses* (nine credit hours required with at least one course in each category. Law 201 may not be included in the minor programs of students in the College of Business and Economics.)

Category I—Case Method

| | |
|---|---|
| Govt 351 | Constitutional Law (3) |
| Govt 352 | Civil Rights (3) |
| Govt 354 | Administrative Law (3) |
| Jour 122 | Law of the Press II (3) |
| Law 201 | Legal Environment of Business (3) |
| Phil 221 (Law 221) | Sex Discrimination and the Law (3) |

Category II—Non-Case Method

| | |
|---|---|
| Clss 161 | Roman Law (3) |
| Hist 260 | American Constitutional and Legal History (3) |
| Hist 357 | English Constitutional and Legal History to 1783 (3) |
| IR 361 | International Law (3) |
| IR 362 | Seminar in International Law (3) |
| Phil 122 | Philosophy of Law (3) |

*required advanced course*

Legal Research Special Topics (3)

This course is taken during the senior year. It aims at developing basic legal research skills and at using at least some of these skills in the execution of a research project focused upon an area of law that is of interest to the student. These projects are approved and supervised by a faculty member affiliated with the program and receive course credit in that faculty member's department.

For further information, consult the program director, J. Ralph Lindgren, philosophy department.

## *Russian Studies*

The minor in Russian Studies is an interdisciplinary program designed to provide a broad range of study of Russian and the Soviet Union. It can be considered the beginning of a specialization in the area that can be continued in graduate school, or a useful area of concentration for certain careers after graduation (e.g., foreign service, governmental employment, business, foreign trade, etc.). The program may also be of general interest to nonspecialist students who wish merely to do focused work on the culture and society of the major country in the socialist world.

The minor in Russian Studies requires eighteen credit hours of formal course work, chosen in consultation with the program director, Donald D. Barry, department of government.

*required courses* (15 hours)

six hours of college-level Russian based on the student's level of competence; **or**

six hours of Russian literature in translation (6)

| | |
|---|---|
| Govt 161 | The Soviet Political System (3) |
| Hist 261 | A History of Russia to 1855 (3) **or** |
| Hist 262 | A History of Russia, 1855 to Present (3) |
| IR 133 | Diplomacy of Russia to 1945 (3) **or** |
| IR 134 | Diplomacy of Russia Since 1945 (3) |

*elective course* (3 credit hours); one course from the following:

any other Russian-language course (3)

any other Russian literature course (3)

| | |
|---|---|
| Govt 318 | Communist Political Systems (3) |
| Eco 309 | Comparative Economic Systems (3) |
| Hist 261 or 262 | (whichever is not taken under Section I) (3) |
| IR 133, 134 or 135 | (whichever is not taken under Section I) (3) |
| IR 315 | The Soviet Union and the Third World (3) |

Special Topics courses in other areas such as psychology or social relations with permission (3)

Field Study in the Soviet Union for academic credit under Special Topics (3)

## *Science, Technology and Society Program*

The Science, Technology and Society (STS) Program is a broad-based effort on the part of faculty members from all colleges to foster undergraduate courses concerned with the interrelationships between scientific and technological advancement and the quality of human life.

The STS program offers a minor in Science, Technology, and Society Studies, consisting of eighteen credit hours drawn from a variety of departments. For a full description of the courses offered, see Section V.

## *Urban Studies*

The minor program in Urban Studies is a means of gaining broad insight into the nature and potentialities of the social sciences, besides being an appropriate vocational choice for students in fields such as civil engineering, management, architecture, and social work.

Urban Studies is designed to promote basic understanding of social processes, so that students will learn to perceive in their ever-changing communities opportunities for productive enterprises of their own. For some this will mean careers in public service, but others may contribute much to the betterment of society by successful work in the private sector. The minor in Urban Studies should be of particular interest to students in the College of Engineering and Applied Sciences as well as the College of Business and Economics who wish to maximize the educational value of their elective courses.

The minor consists of eighteen credit hours of course work selected in consultation with the program director, based on the needs and interests of the student with due concern for the overall intellectual coherence of the program.

Certain other courses in relevant disciplines may be included by permission of the director of urban studies, David Curtis Amidon, Jr., minor adviser, 232 Chandler-Ullmann.

*required course* (3 credit hours)

| | |
|---|---|
| US 61 | The Study of Urbanization (3) |

*elective courses* (15 credit hours); from the following:

| | |
|---|---|
| Arch 210 | 20th-Century Architecture (3) |
| Arch 213 | The City (3) |
| Govt 77 | Urban Politics (3) |
| Govt 331 | Government and Law Internship (3) |
| Govt 360 | Public Administration (3) |
| Hist 333 | American Urban History to 1885 (3) |
| Hist 334 | American Urban History, 1880 to Present (3) |
| US 62 | Contemporary Urban Issues (3) |
| US 125 | American Ethnic Groups (3) |
| US 363 | Philadelphia: Development of a Metropolis (3) |
| Eco 312 | Urban Economics (3) |
| Eco 337 | Transportation and Spatial Economics (3) |
| Eco 354 | Public Finance: State and Local (3) |
| Anth 128 | Urban Ethnology (3) |
| Anth 151 | Utopias and Alternative Communities (3) |

## *Women's Studies*

The interdisciplinary Women's Studies Program, located primarily within the College of Arts and Science, seeks to broaden knowledge about issues related to sex roles and society. The program offers a minor, consisting of eighteen credit hours, that represents the major research fields of Women's Studies. This minor program is open to anyone in the three undergraduate colleges.

In every society the distinction between the sexes is a significant factor in an individual's life. Socialization according to sex affects a person's expectations about appropriate work, social relations, and political position. By focusing attention on those spheres of life in which men have played dominant roles, traditional disciplines have tended to neglect the contribution of women to society and to underestimate the impact of gender differences upon social structure and human lives.

The women's studies minor is a supplement to any undergraduate major. It provides an integrated approach to the role of women in society from the viewpoints of a variety of academic disciplines. The program has three major goals: to promote an understanding of the traditional status and changing roles of women; to stimulate a critical examination of existing sexual roles and stereotypes and the evaluation of alternative arrangements; and to connect issues addressed in the classroom with those raised in the contexts of individual lives and society.

The minor consists of the basic course, Arts and Science 11, Sex Roles and Society, and a choice of five additional courses among those listed below. With the consent of a participating instructor, a student may substitute one Special Topics course. Students arrange their program in consultation with the director of the program, Elizabeth Fifer, department of English, Maginnes Hall.

*required course* (3 credit hours)

| | |
|---|---|
| A&S 11 | Sex Roles and Society: Continuity and Change (3) (team-taught by the faculty of the Women's Studies Program) |

*elective courses* (15 credit hours)

| | |
|---|---|
| Art 111 | Women in Art (3) |
| Clss 152 | Women in Antiquity (3) |
| Engl 191 | Special Topics (1-3) |
| Engl 311 | Literature of Women (3) |
| Govt 179 | The Politics of Women (3) |
| Hist 325 | American Social History, 1607-1877 (3) |
| Mgt 472 | Special Topics (1-3) |
| Phil 221 | Sex-Discrimination and the Law (3) |
| Psyc 131 | Psychology of Women (3) |
| Rel 153 | Sex & Gender in Religious Traditions (3) |
| SR 41 | Human Sexuality (3) |
| Soc 341 | Women and Health (3) |
| Soc 364 | Lifestyle and the Family (3) |

# College Scholar Program

The College Scholar Program offers the qualified student a unique opportunity for maximum enhancement of critical faculties, abilities, and intellectual interests. This end is achieved through a structured program conforming to exceptional standards of breadth and rigor.

Undergraduates in the College of Arts and Science may apply for acceptance into the program at any time during the college career. An application is made to an honors committee, and acceptance is governed by the performance of the student to date and the committee's estimate of the likelihood that he or she will be able to fulfill the requirements of the program.

In order to be graduated with the designation "College Scholar," a student fulfills the requirements and achieves a cumulative average of 3.5.

Each student is required to have an individually structured program that must be approved by the director of the College Scholar Program. No course taken pass/fail may be used to satisfy the requirements. The requirements:

## *Area of Concentration*

**The major.** "College Scholar" candidates may have departmental or interdepartmental majors. The academic level expected of candidates in the area of concentration can be attained by satisfactory completion of courses such as those at the 400 level, independent study, etc.

**Thesis.** The student takes a certain number of hours in independent study or thesis courses, culminating in a thesis or research report. This is read and rated by an ad hoc committee of three faculty members, one of whom must be from outside the department or departments in which the student is doing major work.

**Comprehensive.** A comprehensive examination in the area of concentration is required; it may be written, oral, or both. A committee in charge of the examination includes at least one person from a department other than that (or those) in which the student is doing major work.

### *Distribution Requirements*

**English.** Engl 1 and either 2, 4, 6, 8, or 10.

**Language.** Proficiency in a classical or modern foreign language is needed, sufficient to complete the work of the fifth semester in any 3-3-3-3-3 sequence of credit hours; in a 4-4-3-3 sequence, completion of a fourth semester is required. There is no restriction on the language acceptable.

**Mathematics.** One course from among: Math 21, 31, or 41.

**Natural Science.** Four courses are chosen from two of the following areas: astronomy, biology, chemistry, geology, physics, and psychology. At least one of these courses shall be in chemistry or physics, and at least one of the four courses shall include the accompanying laboratory course.

**Social Science.** Four courses are taken from the areas of archaeology, economics, government, history, international relations, psychology, social relations, and urban studies. At least one must be in economics and one in history.

**Humanities.** Four courses are chosen from the areas of speech and theater, literature (English and advanced courses in classical and modern foreign languages), music, philosophy, and religion studies. At least one of these courses must be in philosophy or religion studies, one in literature, and one in the creative arts (theater, music, and art and architecture).

Note: Each of the last three requirements is stated in terms of *areas*, not *departments*, in recognition of the fact that not all humanities courses are offered in the departments whose names appear under "Humanities," not all historical courses are offered by the history department, not all philosophy courses by the philosophy department, etc.

The committee makes the decision, in consultation with the appropriate departments, under which rubric a specific course may be counted. It also is empowered to admit what substitutions it deems wise.

## Pre-Law Programs

The university has a strong pre-law tradition. In keeping with the policy of the Association of American Law Schools, the university does not have a prescribed pre-law program.

Lehigh students have been successful in attaining entrance into law schools from diverse curricula in all three of the undergraduate colleges.

An active student-run Pre-Law Society brings members of the legal professional and law school personnel on campus for discussion meetings and continuously provides information about law school opportunities.

Law-related courses, some of which rely on the casebook method, are provided by both the College of Arts and Science and the College of Business and Economics. In the former, for example, there is a course in International Law. In the latter, courses in law are regularly offered by the department of law and business.

Counseling is available to prospective prelaw students on a continuous basis from freshman orientation through the law school application process in the senior year. Counselors are members of the prelaw advisory committee, composed of faculty members of both colleges. Students are urged to consult members of the committee as early as possible in their academic careers.

Details on the Law and Legal Institutions minor program are found elsewhere in this section.

## Health Professions Programs

Schools of medicine, dentistry, and veterinary medicine stress the importance of a broad general education as well as prescribed studies in the sciences. As long as candidates have the essential courses in biology, chemistry, physics, and mathematics, they may major in any of the three undergraduate colleges.

A health professions advisory committee, which includes faculty members from biology, chemistry, engineering, and physics, provides information during freshman orientation to interested students and actively works with health-professions candidates from the sophomore year forward to assist them in planning for entrance into professional schools in conjunction with their major advisers.

The university affords a special baccalaureate/doctor of medicine degree program for students interested in becoming physicians, and a doctor of dental medicine program for students interested in becoming dentists. A bachelor of arts in premedical science program is associated with the Medical College of Pennsylvania. A bachelor of arts program in predental science is available in connection with the University of Pennsylvania School of Dental Medicine. Descriptions of these accelerated courses follow.

Students interested in optometry, pharmacy, podiatry, and other allied health fields may obtain information from the health professions advisory committee in planning their courses with their academic advisers.

### *Accelerated M.D. Program*

In cooperation with the Medical College of Pennsylvania, the university offers an accelerated six-year program that enables selected students to earn both the bachelor of arts degree in premedical science and the M.D. degree after a minimum of six years of study at the two institutions. The program was initiated in 1974, and approximately fifteen students are admitted each year.

The program includes two academic years and two summers at Lehigh, during which time ninety-one credit hours are earned toward the 121 required for the baccalaureate degree. Students entering Lehigh with sufficient advanced placement credit may minimize or eliminate the second summer session. The next four years are spent in the regular program of medical education at the medical college. After the first two years at the medical college, students will have acquired the necessary additional credit hours for the baccalaureate degree.

During the first two years at Lehigh, students are expected to make satisfactory progress in the academic areas as well as in the more subtle task of personal growth in those attributes ultimately needed as a physician. Seminars are conducted on campus by Medical College of Pennsylvania faculty members, and students are assigned to MCP faculty advisers. MCP receives student grades and monitors student progress through regular counseling sessions and feedback from Lehigh staff.

MCP has specifically avoided setting arbitrary standards for performance in order to encourage students to pursue the more difficult courses and to range into new academic and extracurricular areas appropriate to the student's academic and personal growth.

The medical college reserves the right to withdraw an offer of acceptance if academic or personal concerns cause the college to question a student's ability to function as a physician. The college also reserves the right to require that a student spend additional time at Lehigh if the medical college feels that this is necessary for the student's academic or personal maturation. Experience with the program to date indicates that such action is rarely necessary. In addition, the student may elect to take additional time at Lehigh prior to matriculation at the medical college if he or she feels that this would be beneficial. Should this occur, the student would be eligible to defer matriculation at medical school for a period of time agreed to by the student and the medical college.

Application for admission to the program is made through the Lehigh office of admission. Criteria for admission include SAT scores (minimum combined score of approximately 1300), scholastic achievement, maturity, and motivation for medicine.

Interviews are not required at Lehigh, but students are encouraged to make arrangements to come to campus to have an interview and to become better acquainted with Lehigh and the special features of the program.

| | |
|---|---|
| **Year 1:** Lehigh, fall | Lehigh, spring |
| A&S 1 (1) | Biol 21, 22 (4) |
| Chem 21, 22 (5) | Math 22 or 44 (3-4) |
| Math 21 or 41 (3-4) | Engl 2, 4, 6, 8, 10 (3) |
| Engl 1 (3) | |

| | |
|---|---|
| Foreign Language (3-4) | Foreign Language (3-4) |
| Humanities (3) | Social Science (3) |
| **Summer 1:** Lehigh | |
| Chem 51, 53 (4) | |
| Chem 52, 58 (4) | |
| Elective (free) (3)* | |
| **Year 2:** Lehigh, fall | Lehigh, spring |
| Phys 11, 12 (5) | Phys 13, 14 (4) |
| Math 23 or Math elective (3-4) | Biol 28 (Genetics) |
| Biology elective (3) | Chem 31 (3) |
| Humanities (3) | Humanities (3) |
| Social Science (3) | Social Science (3) |
| | Performing Arts (3) |
| **Summer 2:** Lehigh | |
| Humanities (3) | |
| Social Science (3) | |
| Elective (free) (3) | |
| Elective free (3) | |

### *Accelerated Program in Dentistry*

The university, in cooperation with the School of Dental Medicine at the University of Pennsylvania, offers an accelerated seven-year program that enables selected students to earn a combined baccalaureate and doctor of dental medicine degree after a minimum of seven years of study at the two institutions.

The program includes three academic years during which time ninety-six credit hours are earned toward the baccalaureate degree. The next four years are spent in the regular program of dental education at the School of Dental Medicine in Philadelphia.

During the first three years at Lehigh, students are expected to make satisfactory progress in the academic areas as well as in the areas of personal growth, developing those attributes ultimately needed to become a dentist. Students must maintain a minimum 3.0 grade-point average throughout their three years at Lehigh.

The dental school reserves the right to withdraw an acceptance if academic or personal concerns cause the college to question a student's ability to function as a dentist. The dental school also reserves the right to require that students spend additional time at Lehigh if the school feels that this is necessary to insure the student's academic or personal maturation.

Application to the program occurs when a student applies to Lehigh University. The dental school takes action on the applicant and interviews candidates from mid-February to mid-March of an academic year. Final decisions are forwarded to Lehigh University about March 20. The applicant is notified of joint acceptance by Lehigh University. Admission is based on SAT scores (a minimum combined score of 1200), scholastic achievement, maturity, and motivation for dental school.

| | |
|---|---|
| **Year 1,** fall | spring |
| A&S 1 (1) | Engl (3) |
| Engl 1 (3) | Math 44 (3) |
| Math 41 (3) | Biol 21, 22 (4) |
| Chem 21, 22 (5) | Foreign Language (3-4) |
| Foreign Language (3-4) | Humanities (3) |
| **Year 2,** fall | spring |
| Chem 51, 53 (4) | Chem 52, 58 (4) |
| Biol 28 (3) | Biol 235 (3) |
| Social Science (3) | Math 42/elective (3) |
| Social Science (3) | Humanities (3) |
| Humanities (3) | Social Science (3) |
| **Year 3,** fall | spring |
| Phys 11, 12 (5) | Phys 13, 14 (4) |
| Biol elective (3) | Biol elective (3) |
| Humanities (3) | Chem 31 (3) |
| Social Science (3) | Elective (3) |
| Performing Arts (3) | Elective (3) |

# College of Business and Economics

Richard W. Barsness, *dean*; Joseph P. Klein, *assistant dean*

The College of Business and Economics offers the bachelor of science degree in business and economics, which couples a liberal educational background with an understanding of the complexities and processes of management. It can serve as the basis for a career in business or for professional studies in fields such as law, business, or related fields. Qualified students can opt to continue their studies for a fifth year and earn a master of business administration degree.

The undergraduate business program, undergraduate accounting program, and MBA programs are accredited by the American Assembly of Collegiate Schools of Business (AACSB), of which the College of Business and Economics is a member. The college offers a program of undergraduate study designed to provide an understanding of the complexities of the managerial process in society, both within and outside the business firm.

Many of the most difficult societal problems today involve decision-making, conflict resolution, and the efficient and effective management of human and physical resources. The study of business and economics provides a basis for understanding and developing solutions to these problems.

Thus the college's undergraduate business program stresses analytical and communication skills, and problem-solving techniques. Educational breadth equivalent to many liberal arts programs is accompanied by in-depth study of business processes such as accounting information systems, financial flows and markets, management processes, and the impact of economic forces upon business and social issues.

## Major Subjects

Five major programs are offered, each leading to the bachelor of science degree. The programs include:
accounting
economics
finance
management
marketing

### *Breadth of Study*

The undergraduate education deemed most suitable for young men and women who will be the business leaders of tomorrow combines broad educational foundations, analytical rigor and in-depth understanding of business operations.

This education in fundamental principles, and problem-solving techniques provides graduates with various options. Some of the students choosing this curriculum have already settled upon business careers. Others will use it as a base for further professional studies in law, graduate business schools, or specialized graduate training in economics, operations research, or other related fields. Still others go into administrative careers in government or nonprofit institutions such as hospitals and universities. Others apply their talents to professional accounting, financial investment, or management consulting careers. Others teach economics or administrative science.

Business today cannot be approached with narrow or superficial vocational training. Its problems are strongly conditioned by the state of the economy and other major social issues. Thus a strong basis in the social sciences is essential to understanding the nature of business organizations. The student also must be familiar with physical sciences and technology. Finally, mathematics and computer systems are essential elements of modern decision-making processes. An introduction to all of these is provided in the undergraduate program in business and economics.

The six college departments in which much of the student's work is carried out are: accounting, economics, finance, law and business, management, and marketing.

### *Variety of Options*

The student of today must be provided with options. Initiative and motivation would be stultified in a rigid curriculum. To avoid such rigidity, the necessary exposures to science, language, and other arts are accomplished by optional requirements, within each of which the student has wide choice. Thus the basic curriculum rationale is similar to a distribution requirement in liberal arts to guarantee breadth of undergraduate educational experience. Additionally, however, approximately twenty credit hours required for graduation are completely open for selection on a free-elective basis.

The degree of bachelor of science in business and economics may also lead to achievement of the master of business administration degree in the college or at another institution.

In addition to the master of business administration, the college also offers the following post-baccalaureate degrees: the doctor of philosophy, the master of arts, the master of science, and the master of science in management science. These are described in Section IV.

## Goals of the College

The objectives of the College of Business and Economics are to provide an understanding (at the undergraduate level) and managerial and/or research-teaching expertise (at graduate levels) of the nature of business enterprise decision-making and resource management in the economy. Undergraduate objectives may be summarized as follows:

- Through a common body of knowledge, to stimulate interest in and acquaint a student with basic business and economic systems of resource allocation, financial management, management of human and physical resources, information systems, financial and managerial accounting, pricing and distribution;
- To provide breadth of appreciation of the scientific, technological, social and human features of the world in which business is carried on;
- To provide tools which permit rigorous analysis of business problems and to foster a capacity for continuing professional development;
- To undertake advanced courses with upperclass students as a prelude to a professional career or to graduate study;
- Through a major, to provide each student with an in-depth learning experience in at least one area of business or the economy in which business operates, such as accounting, finance, economics, economic statistics, foreign careers, management or marketing;
- To increase written and oral communication skills.

## Centers and Institutes

The college also oversees research and scholarship in a number of centers and institutes, where graduate and undergraduate students work closely with faculty members. These include: Center for Economic Education, Center for Innovation Management Studies, Center for Social Research, Martindale Center for the Study of Private Enterprise, Institute for the Study of Commodities, Rauch Center for Business Communications, Goodman Center for Real Estate Studies, and Musser Center for Entrepreneurship.

The college is also associated with the International Business Institute in the Center for International Studies.

## Bachelor of Science in Business

To obtain the bachelor of science degree in business and economics, 123 credit hours are required.

Beginning with the class of 1991 (entering freshmen of 1987), a "writing skills" requirement will be a part of the college curriculum requirements for all students in the College of Business and Economics.

### *College Core Requirements (58 credits)*

*English and mathematics (12 credits)*

| | |
|---|---|
| Engl 1 | Composition and Literature (3) |
| Engl 2, 4, 6, 8 or 10 | Composition and Literature: Fiction, Drama, Poetry (3) |
| Math 41 | BMSS Calculus I (3) |
| Math 44 | BMSS Calculus II (3) |

Note: BMSS stands for biological, management and social science.

*Business and economics core (46 credits)*

| | |
|---|---|
| Eco 1 | Economics (4) |
| Mgt 1 | Introduction to Business Computing (3) |
| Eco 145 | Statistical Methods (3) |
| Eco 229 | Money and Banking (3) |
| Eco 105 | Intermediate Microeconomic Analysis (3) |
| Eco 119 | Intermediate Macroeconomic Analysis (3) |
| Acct 51 | Introduction to Financial Accounting (3) |
| Acct 52 | Introduction to Managerial Accounting (3) |
| Acct 111 | Management Information Systems in Business (3) |
| Law 201 | Legal Environment of Business (3) |
| Mkt 211 | Contemporary Marketing (3) |
| Fin 225 | Business Finance (3) |
| Mgt 269 | Management of Operations in Organizations (3) |
| Mgt 270 | Organization Theory and Behavior (3) |
| Mgt 301 or Mgt 306 | Business Management Policies (3) **or** Entrepreneurship and Business Policy (3) |

### *Major Program (15credits)*

Before the end of the first semester of the junior year, students select a major or field of concentration. A major program consists of sequential or related courses in accordance with one of the designated major programs, as detailed in Section V. Five majors are offered: accounting, economics, finance, management, and marketing.

Beginning with the class of 1992 (entering freshmen of 1988), a grade point average of 2.0 or higher in the major program is required for graduation.

### *Optional Courses (30 credits)*

The student elects three credit hours of courses from each of the following four groups:

1. Offerings in English, speech, journalism, theater, or modern foreign languages.
2. Offerings in the government, history, international relations, psychology, and social relations departments (including urban studies).
3. Offerings in the art and architecture, classics, mathematics, music, religion studies, and philosophy departments.
4. Offerings in the biology, chemistry, geological sciences, and physics departments.

The remaining eighteen credit hours are taken in any one or more of the departments listed in the four groups above or any one or more departments in the College of Arts and Science, as follows: biology, classics, English, art and architecture, geological sciences, government, history, international relations, mathematics, modern foreign languages and literature, music, philosophy, psychology, religion studies, and social relations. One-hour courses are not accepted for the optional courses but may be counted toward electives.

### *Electives (20 credits)*

Normally, any courses for credit in the university for which a student has the prerequisites may be used as electives.

Advanced military science and aerospace studies courses may be counted as electives up to six credits, but freshman- and sophomore-level courses in military science and aerospace studies do not carry credit against the 120 credit hours required for graduation.

## *Planning Courses of Study*

In addition to freshman English and mathematics requirements, each freshman enrolled in the College of Business and Economics registers for Eco 1 and/or Mgt 1.

For the fourth and possibly fifth courses, the freshman student takes courses toward the optional requirement each semester of the freshman year. The normal program for freshmen is fifteen credit hours each semester.

Acctg 51 is taken in the first semester of the sophomore year. Other business and economics core requirements should be selected with some sampling of introductory courses that may help the student choose the major in the junior year.

The pass-fail option is available for students in the college for elective credits. Courses with passing letter grades must be submitted to meet the core, major program, and optional requirements. Courses taken on a pass-fail basis are classified as elective courses. Students desiring to obtain Lehigh credit for courses taken at other institutions must obtain a petition form from the registrar's office and obtain the approval of appropriate Lehigh academic departments *in advance.* The senior-year work must be taken at Lehigh.

## *Course Sequence*

**Freshman Year**

| | *first semester* | | *second semester* | |
|---|---|---|---|---|
| Engl 1 | 3 credit hours | Engl 2, 4, 6, 8, 10 | 3 credit hours |
| Math 41 | 3 | Math 44 | 3 |
| Eco 1 | 4 | Mgt 1 | 3 |
| electives | 6 | electives | 6 |
| | 16 credit hours | | 15 credit hours |

Note: The college assigns students to take Eco 1 in either the fall or spring semester. A similar assignment is made for Mgt 1. The student registers for six credit hours of electives in both semesters to round out the normal course load.

**Sophomore Year**

| | *first semester* | | *second semester* | |
|---|---|---|---|---|
| Acctg 51 | 3 credit hours | Acctg 52 | 3 credit hours |
| Eco 145 | 3 | Acctg 111 | 3 |
| Eco 105 | 3 | Eco 119 | 3 |
| electives | 6 | electives | 6 |
| | 15 credit hours | | 15 credit hours |

Note: Many sophomore courses can be taken in either semester.

# College of Education

The university's College of Education offers opportunities for advanced study in the field of education. For information, see Graduate Study in Education, Section IV, or College of Education, Section V.

# College of Engineering and Applied Science

Alan W. Pense, *dean;* George E. Kane, *associate dean*

The College of Engineering and Applied Science offers the bachelor of science degree in thirteen programs, combining a strong background in sciences and mathematics with General Studies requirements in humanities and social sciences. Students in college programs learn principles they can apply in future professional work; those who plan on further academic experience can design a curriculum centering on interests they will pursue in graduate school.

In the past engineering education was identified in terms of the needs of industry. Present-day engineering programs continue to provide and emphasize such preparation. However, the flexibility inherent in the curricula enables students to design personalized programs leading directly into other professional colleges or professions such as medicine, law, government, management, or architecture.

The college encourages such mobility. Experience shows that the background provided through the college programs, including "the engineering approach" to identification, articulation and resolution of problems, finds increasingly wider applicability in those areas of activity that call for a combination of practical and conceptual intelligence.

The college recognizes that the four-year programs are not intended to train specialists in a given area but rather to educate students in terms of principles they will apply to problems they encounter in their future professional work.

The applied curricula of the college stress fundamentals while providing opportunities for electives in each of the substantive fields within the sciences. Senior-year programs in the sciences can be planned to facilitate transition to either graduate school or industrial laboratories.

## Major Subjects

The College of Engineering and Applied Science includes six departments and offers undergraduate and graduate degree programs at the bachelor, master, and doctor of philosophy levels.

The undergraduate degree programs or curricula leading to the bachelor of science degree are:

chemical engineering*
chemistry or biochemistry
civil engineering*
computer science**
computer engineering*
electrical engineering*
fundamental sciences
industrial engineering*
mechanical engineering* and mechanics*
materials science and engineering*
physics

*Accredited by the Accreditation Board for Engineering and Technology. Programs in chemistry and physics have been approved by the program review committee in these disciplines.

**Accredited by the Computing Science Accreditation Board, Inc.

Information about each of these programs may be found under alphabetical listings in Section V.

Each of the curricula includes course requirements in the physical sciences, mathematics, engineering sciences, and the advanced engineering or science course work essential for the particular degree. In addition, each curriculum has General Studies requirements in the humanities and social sciences.

Undergraduates with interests in such topical areas as environmental control, biotechnology, or aerospace can pursue their interests through electives provided in each of the curricula. Effective preparation for graduate study in such specialties consists of basic programs in engineering and science, along with electives especially chosen for the field of interest. Such electives are chosen from among all the offerings of the university and usually taken during the senior year.

## *Personal Electives*

The college, through its advisers, is prepared to help students to use the six credit hours of "free electives" that, along with other electives in the curriculum, may be used to develop a program of personal interest. Free electives may be satisfied by taking regular course offerings or six credit hours from Mus 21-78, or six credit hours from Jour 1-8, or six credit hours of advanced ROTC courses.

Students who do a co-op assignment or have significant involvement in noncredit major extracurricular activities may have up to six credit hours of free electives waived upon petition to the department chairperson. These petitions must be completed and approved *prior* to the final semester before graduation.

Qualified juniors in the college planning to continue their formal education in graduate school are urged to take advantage of the flexibility in their programs and design their senior-year "free elective" opportunities in a manner that provides an effective foundation for a graduate program. Students who plan their programs in this manner can, upon recommendation of the department and with the approval of the dean of the Graduate School, receive credit towards their degree for up to six hours of graduate-level courses.

# Technical Minors

In addition to the General Studies minor, other minors are offered in technical or scientific specialties that are not normally included within the normal curricula. Each program contains at least fifteen credit hours of technical and/or scientific courses. Often some of these courses can be chosen as approved electives in the student's major curriculum; others are chosen as free electives.

Technical and scientific minors are available in chemical processing (not open to chemical engineers), molecular biophysics (not open to engineering physicists or fundamental sciences majors concentrating in this area), production management (not open to industrial engineers), fluid mechanics, and solid mechanics.

In some special cases a student in the college, able to incorporate electives within the curriculum that satisfy the requirements of a minor offered in the College of Arts and Science, can, with the permission of the adviser in that college, earn the minor.

## *Recommended Freshman Year In Engineering and Applied Science*

The following is the recommended outline of work for the freshman year, satisfying the requirements for all students in the college. For schedules of the work required in the following three years, refer to Section V.

**Freshman year, first semester** (15-16 credits)

| | |
|---|---|
| Engl 1 | Composition and Literature (3) |
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) **or** |
| Phys 11, 12 | Introductory Physics I and Laboratory (5) |
| Math 21 | Analytic Geometry and Calculus I (4) |
| Engr 1 | Engineering Computations (3) **or** |
| General Studies, elective (3 or 4) | Humanities, or Social Science (GS) elective (3-4) |

**Freshman year, second semester** (15-16 credits)

| | |
|---|---|
| Engl 2 | Composition and Literature: Fiction, Drama, Poetry (3) * |
| Phys 11, 12 | Introductory Physics I and Laboratory (5) **or** |
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |
| Math 22 | Analytic Geometry and Calculus II (4) |
| Engr 1 | Engineering Computations (3) **or** |
| General Studies, elective (3 or 4) | Humanities, or Social Science (GS) elective (3-4) |

*Engl 4, 6, 8, or 10 may replace Engl 2.

# General Studies Program: Humanities for Engineers

The General Studies (GS) program involves a minimum of twenty-five credit hours normally spread over four years. It is designed to enable students to range widely or to delve deeply into the humanities or the social sciences with the purpose of exploring the value systems, assumptions, and methodologies contained in these areas.

Since all students in the college are expected to complete specified sequences of courses in the physical sciences, and other electives are available for related courses in natural sciences, the General Studies program is restricted to the humanities and social sciences.

In addition, students pursuing a bachelor of science degree program in the college can, if they so choose, organize their General Studies program to achieve a minor in any one of the established areas in the humanities or social sciences. This requires:

1. Identifying the area of interest, i.e., sociology, philosophy, art and architecture, literature, etc., and obtaining the approval of the director of the General Studies program. A conference with the director is the first step toward this goal.
2. Formulating a course program in the area of concentration jointly with a member of the faculty representing the area of concentration. The names of faculty representatives are given to students by the director of General Studies.

In general, the minor is earned upon successful completion of a program of not less than fifteen credit hours in the area of concentration. In each and every case the faculty adviser in the area of concentration or the director of General Studies must recommend the student's work for such recognition. It is desirable that students planning to earn a minor in General Studies initiate action soon after their freshman year but not later than the beginning of the fifth semester.

The General Studies sequence of the college starts in the freshman year with six hours of English composition and literature, and a three-credit-hour social science or humanities elective. In the sophomore year, four credit hours of economics are required. By the end of the senior year, a minimum of twelve additional credit hours (four courses) is completed to satisfy the requirement of a total of twenty-five credit hours in General Studies.

Accreditation criteria require at least one of the humanities or social science electives to be beyond the introductory level.

Courses qualifying for credit in General Studies are as follows:

**Required Courses** (10 credit hours)

Engl 1 or 11, and one course from among Engl 2, 4, 6, 8, 10 or 12; Eco 1

**Electives in humanities and social science** (15 credits)

Anthropology, any course

Art and architecture, any except Arch 145

Classics, any course

Computer Science

| | |
|---|---|
| CSc 252 | Computers and Society (3) |
| CSc 301 | Descriptive Linguistics (3) |

Economics

| | |
|---|---|
| Eco 105 | Intermediate Microeconomic Analysis (3) |
| Eco 119 | Intermediate Macroeconomic Analysis (3) |
| Eco 229 | Money and Banking (3) |
| Eco 303 | Economic Development (3) |
| Eco 305 | The Economic Development of Latin America (3) |
| Eco 309 | Comparative Economic Systems (3) |
| Eco 310 | Economic Evolution (3) |
| Eco 311 | Environmental Economics (3) |
| Eco 312 | Urban Economics (3) |
| Eco 313 | History of Economic Thought (3) |
| Eco 314 | Energy Economics (3) |
| Eco 334 | Labor-Management Relations (3) |
| Eco 335 | Labor Economics (3) |
| Eco 336 | Business and Government (3) |
| Eco 337 | Transportation and Spatial Economics (3) |
| Eco 340 | International Finance (3) |
| Eco 343 | European Economic Integration (3) |

English, any course

Foreign language, any advanced course. If elementary modern language study is elected, a minimum of one year must be in one language in order to receive General Studies credit.

A student may not elect an elementary course in any language studied in high school without approval of the department of modern foreign languages.

Freshman Seminar

Government and Urban Studies, any course

History, any course

International Relations, any course

Journalism

| | |
|---|---|
| Jour 114 | Reporting of Public Affairs (4) |
| Jour 118 | History of American Journalism (3) |
| Jour 121 | Law of the Press (3) |
| Jour 122 | Law of the Press II (3) |
| Jour 123 | Basic Science and Technical Writing (3) |
| Jour 124 | Politics of Science (3) |
| Jour 125 | Environment, the Public and the Mass Media (3) |
| Jour 131 | Science Writing Practicum (1-3) |
| Jour 141 | Photojournalism (3) |
| Jour 211 | Problems in Advanced Reporting (3) |
| Jour 311 | Science and Technical Writing (3) |
| Jour 312 | Advanced Science Writing (3) |
| Jour 313 | Special Topics in Science Writing (3) |
| Jour 315 | Interpretive Writing (3) |
| Law 11 | Introduction to Law (3) |

Music, any course other than Mus 21 through 78

Philosophy, any course except Phil 14

Psychology

| | |
|---|---|
| Psyc 1 | Introduction to Psychology (3) |
| Psyc 11 | Introduction to Psychology: Discussion Format (3) |
| Psyc 21 | Social Psychology (3) |
| Psyc 31 | Normal and Altered States of Consciousness (3) |
| Psyc 65 | Perception and the Visual Arts (3) |
| Psyc 77 | Drugs and Behavior (3) |
| Psyc 81 | Psychology and Law (3) |
| Psyc 107 | Child Development (3) |
| Psyc 108 | Adolescent Development (3) |
| Psyc 109 | Adulthood and Aging: Social and Psychological Perspectives (3) |
| Psyc 115 | History of Modern Psychology (3) |
| Psyc 117 | Cognitive Psychology (3) |
| Psyc 131 | Psychology of Women (3) |
| Psyc 154 | Introduction to Clinical Psychology (3) |
| Psyc 201 | Industrial Psychology (3) |
| Psyc 305 | Abnormal Psychology (3) |
| Psyc 331 | Humanistic Psychology (3) |
| Psyc 351 | Cognitive Development in Childhood (3) |
| Psyc 353 | Personality Theory (3) |
| Psyc 354 | Personality Assessment(3) |

Science, Technology and Society, any course

Religion Studies, any course

Social Psychology, any course except S Psy 391, 392

Social Relations, any course

Theatre, any course except Thtr 61, 111, 116, 161. Thtr 175 or 351 by petition

## Change of Curriculum

The early indication of curriculum choice by students in their application to the university is not a commitment on their part. In the second semester of the freshman year, at preregistration for the sophomore year, students usually indicate their choice of curriculum.

However, since the sophomore-year programs for several curricula are very much alike, it is possible to transfer from one curriculum to another as late as the end of the sophomore year. This is done by means of a petition following consultation with curriculum advisers. There are instances where such a transfer may require one or two courses to be taken during a summer session at Lehigh or elsewhere.

Five-year programs combining the liberal arts and engineering or electrical engineering and physics are also available. In each of these combined curricula, one bachelor degree is awarded upon the successful completion of four years of study, and a second bachelor degree is awarded at the end of the fifth year.

The college curricula are designed to provide students with as much latitude as can be made available without compromising the balance and integrity expected of them by accrediting agencies.

## Centers and Institutes

Faculty and students in the college also have research and scholarship activities in a number of centers and institutes, where graduate and undergraduate students work closely with faculty members. These include: Center for Advanced Technology for Large Structural Systems, Bioprocessing Institute, Center for the Application of Mathematics, Center for Design and Manufacturing Innovation, Center for Environmental Studies, Center for Health Sciences, Center for Innovation Management Studies, Center for Molecular Bioscience and Biotechnology, Chemical Process Modeling and Control Center, Emulsion Polymers Institute, Energy Research Center, Fritz Laboratory, Institute for Robotics, Institute for the Study of the High-Rise Habitat, Institute of Fracture and Solid Mechanics, Institute of Metal Forming, Institute of Thermo-Fluid Engineering and Science, Materials Research Center, Sherman Fairchild Center for Solid-State Studies, Zettlemoyer Center for Surface Studies.

# The General College Division

The General College Division supplements the mission of the established undergraduate curricula by providing: an opportunity for persons not planning to qualify for a degree to pursue work, either of a general or specialized nature, which their preparation and interests make desirable; a trial period for those who wish to become candidates for baccalaureate or graduate degrees, but whose preparation does not satisfy the entrance requirements for the established curricula; and an opportunity for qualified students to continue their education without being committed to a restricted or specialized program of studies. Courses taken in the General College Division may not be submitted to meet the requirements for a graduate degree.

For admission to the General College Division, the applicant must show maturity, seriousness of purpose, and evidence of ability to pursue with profit the program of studies he or she desires. The student must have the established prerequisites for courses in which he or she wishes to enroll, and may register for courses up to and including the 300-level.

There is no established curriculum for the General College Division. Each student works on a program outlined to meet his or her special needs. Each program must be approved by the director of the division.

Students in the division are not candidates for degrees. A student may transfer to regular matriculated undergraduate status in any of the colleges only upon petition to, and with the approval of, the committee on standing of students. Transfer to the graduate school is possible only through the normal graduate admission process.

Transfers from regularly matriculated status in any of the colleges to the General College Division may be made only with the approval of the committee on standing of students. Transfers from the Graduate School require the approval of the graduate committee.

With the exception above, students in the General College Division are subject to the same rules and regulations as students of the university. They pay the tuition and fees established for regularly matriculated students.

# Continuing Education and Summer Sessions

Lehigh University departments, research centers, and administrative agencies offer a varied selection of continuing education programs for

adults. Reflecting Lehigh's educational strengths, these offerings include career enrichment, professional development, and sophisticated technical training programs. They often provide tools and techniques applicable to specific problems of corporations and other organizations. These programs carry no regular academic credit, but participants can earn Continuing Education Units (CEUs). In awarding CEUs, Lehigh follows the guidelines developed by the National Council on the Continuing Education Unit.

Lehigh continuing education programs are self-contained educational packages designed to meet specific needs. Their content, schedules, and timing are adapted to best serve the audiences for which they have been developed. Continuing education instructors are generally drawn from the Lehigh faculty, but distinguished men and women from industry and other educational institutions are often involved as well. A number of programs are available for "in-house" presentation to organizations on a contract basis.

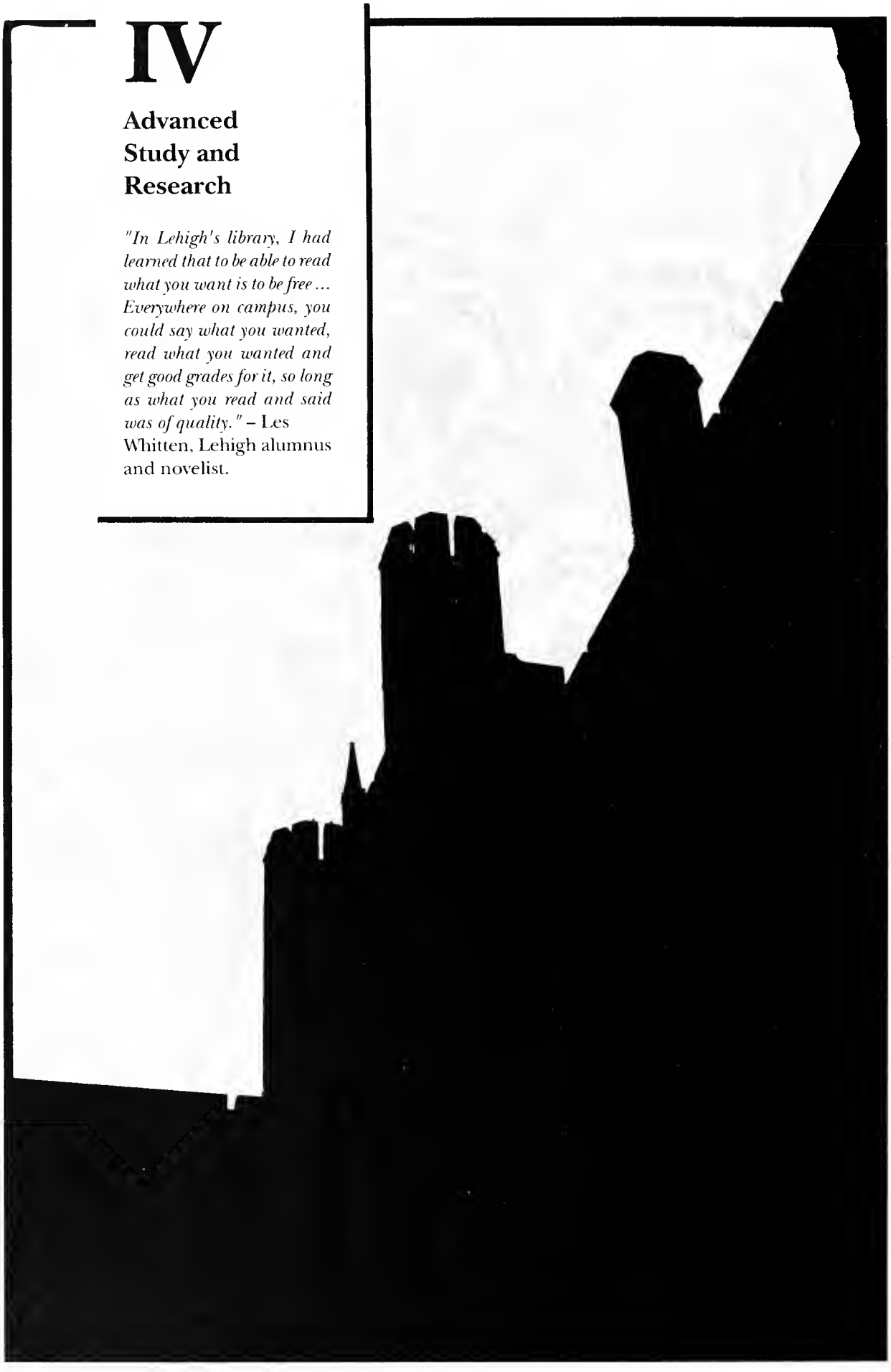
Summer sessions have been conducted at Lehigh University for nearly a century. Presently featuring more than 200 credit courses, this program serves Lehigh's regular graduate and undergraduate population, area teachers and other professionals, and students from other institutions of higher learning who return to their homes in the Lehigh Valley during the summer. At Lehigh, the summer is a time in which experimentation is encouraged. The result is often innovative courses that are unavailable at other times of the year.

For more information about continuing education or summer sessions at Lehigh, contact the Office of Continuing Education and Summer Sessions, 219 Warren Square, Lehigh University, Bethlehem, Pa. 18015, (215) 758-3935 or (215) 758-3966.

# IV

## Advanced Study and Research

*"In Lehigh's library, I had learned that to be able to read what you want is to be free... Everywhere on campus, you could say what you wanted, read what you wanted and get good grades for it, so long as what you read and said was of quality."* – Les Whitten, Lehigh alumnus and novelist.



# IV.

# Graduate Study and Research

## The Graduate School

David A. Thomas, dean of Graduate Studies

Lehigh began awarding graduate degrees in 1882. The first recipient, T.H. Hardcastle, of the Class of 1880, wrote his thesis on Alexander Pope, entitled it The Rights of Man, and read it aloud at commencement in June 1882.

The first Ph.D. was granted in 1895 to Joseph W. Richards, Class of 1886. Richards, who had a background in metallurgy and electrochemistry, taught at Lehigh until his death in 1921.

Women were admitted to the graduate program in 1918 when the faculty and the board of trustees agreed to grant the degrees of M.A. and M.S. to women, provided they attended classes in the late afternoon and on Saturdays "so that the general character of campus life shall not be affected." Three women received graduate degrees in 1921, the first women to complete graduate work at Lehigh. In 1929, the rule was changed, and women were admitted on much the same basis as men.

In 1936, the Graduate School was established to administer the graduate program. The Ph.D., which was temporarily discontinued in 1894, was reinstated in nine departments: chemistry, chemical engineering, civil engineering, geology, history, mathematics, mechanical engineering, metallurgical engineering, and physics. Tomlinson Fort, professor of mathematics, was selected in 1938 as the first dean of the Graduate School.

In 1961, the university officially resolved to strengthen and expand graduate programs university-wide. Since then, graduate work has assumed increased importance and prominence, and facilities and funding have increased tremendously.

### College of Arts and Science

James D. Gunton, dean

Within the College of Arts and science, professionally oriented students may pursue advanced degrees in biology (M.S., Ph.D.), chemistry (M.S., Ph.D., D.A.), English (M.A., Ph.D.), geology (M.S., Ph.D.), government (M.A., M.P.A.), history (M.A., Ph.D.), mathematics (M.S., Ph.D.), physics (M.S., Ph.D.), psychology (M.S., Ph.D.), social relations (M.A.)., and applied social research (Ph.D.).

Although degree requirements vary from department to department, most departments require a combination of formal coursework and independent research. Students work closely with a faculty adviser both in formulating and carrying out their research programs. Given the nature of the liberal arts, these programs commonly involve faculty and/or coursework from more than one department or a department and research center/institute. Students interested in such an interdisciplinary approach are admitted to a single department but formulate a program of study and research that draws on faculty and facilities in other areas of the university. Superior candidates may qualify for financial support in the form of teaching assistantships, graduate assistantships, research assistantships, scholarships, or university fellowships.

### College of Business and Economics

Richard W. Barsness, dean

The College of Business and Economics offers the master of science degree in economics, master of business administration, master of management science, and the doctor of philosophy degree in business and economics.

Graduate education in the College of Business and Economics distinguishes by emphasis between professional management training through the M.B.A., which generally, though not always, concludes at the master's level, and graduate pursuit of business and economics subjects in depth for research and/or teaching expertise through the doctoral and related M.S. programs.

There are six departments in the college: accounting, economics, finance, law and business, management, and marketing. Course descriptions can be found listed under these departments in Section V; more information about the various degree programs appears below. The college publishes a brochure describing its graduate programs, which may be obtained by writing to the Graduate School, Whitaker Laboratory 5, Bethlehem, Pa. 18015.

### College of Education

Alden J. Moe, dean

The College of Education offers the master of arts in education, the master of education, the master of science in education, the educational specialist, the doctor of education, and the doctor of philosophy. More information about these degrees appears below.

The College was established as the School of Education in 1966, elevating it from its former departmental status under the College of Arts and Science. In 1985 the school was given its present status as a college, headed by a dean. The College is engaged in the preparation of elementary and secondary teachers in both school and nonschool settings, school and community counselors, counseling psychologists, school psychologists, school and college administrators, reading specialists and supervisors, curriculum specialists and supervisors, specialists in the foundations of education, specialists and supervisors in the education of mentally and emotionally disturbed children, teachers of preschool children (especially children with handicaps), teachers for the social restoration of potential delinquents, and specialists in educational technology.

The College of Education is interested in potential and established leaders in all aspects of educational endeavor. A total of 559 students are involved in advanced study at the master's and doctoral levels during the 1988-89 academic year.

Through its working relationship with other colleges and universities in eastern Pennsylvania, Lehigh has undertaken to complement existing undergraduate preparation programs by emphasizing study at the graduate level. Off-campus course work and in-service projects are integral parts of many programs.

An intern teaching program is specifically designed for qualified persons who hold bachelor of arts degrees and who desire to enter the field of teaching. Those admitted to this program have the opportunity to accomplish their professional training and serve as interns in the public schools. After two semesters of directed full-time study, students may begin the teaching internship. Upon completion of the fifth-year program and the required semesters of intern teaching, these students ordinarily will have completed requirements for the M.A. (secondary teachers) or the M.Ed. (elementary teachers), as well as state certification.

**Organization.** The College of Education is organized into two departments and eight program areas. The departments are the Department of Counseling Psychology, School Psychology, and Special Education, and the Department of Leadership, Instruction, and Technology. The eight program areas, each having its own coordinator, are administration and supervision, counseling, educational technology, reading, school psychology, social restoration, special education, and teacher education.

**Centennial School.** The College of Education operates the Centennial School—a laboratory facility for exceptional children that has both an elementary and a secondary component. Centennial School provides research opportunities as well as practical experience for advanced students in counseling, school psychology, special education, and reading. The laboratory facility is housed in a former elementary school in the Bethlehem community.

**Undergraduate minor in education.** Upper-level undergraduates are given an opportunity to take a minor in education that combines practicum activities with theoretical work and is designed to provide a foundation for further educational studies at the graduate level.

# College of Engineering and Applied Science

Alan W. Pense, dean

The College of Engineering and Applied Science offers the master of science, master of engineering, and doctor of philosophy degrees in each of its six academic departments and in interdisciplinary programs as well. Each department creates its own course, examination, and thesis or dissertation requirements within the framework of those established by the Graduate School. The departments in the college offering graduate degrees are chemical engineering, civil engineering, computer science and electrical engineering, industrial engineering, mechanical engineering and mechanics, and materials science and engineering.

Graduate study in the College of Engineering and Applied Science is closely related to the college's extensive research activity, and all graduate students are expected to engage in analytical or experimental research as part of their programs of study. This activity involves students in the process of creation of new knowledge under the direction of the college's distinguished faculty and brings them into contact with some of the most modern and advanced experimental techniques. Many college research programs are supported by contracts, fellowships, and grants from industry and from federal, state, and local governments. This funding not only provides financial support for outstanding students but also allows them to deal with some of the more complex and pressing problems facing our society now and in the 21st century.

Many faculty members and graduate students in the College of Engineering and Applied Science are associated with interdisciplinary research centers and institutes as well as with their own departments. This opportunity for interdisciplinary study allows them to cross departmental lines in specific technological areas and to work with faculty and graduate students from other departments. Centers and institutes currently carry on research in the areas of biotechnology, applied mathematics, health sciences, thermofluids, materials, energy, marine and environmental sciences, surfaces and coatings, solid-state studies, structural and geotechnical studies, high-rise habitats, emulsion polymers, fracture and solid mechanics, metal forming, robotics, computer-integrated manufacturing, and design and management innovation. Extensive research in many of these areas is also conducted with academic departments. All students in interdisciplinary degree programs are associated with specific academic departments.

## Admission to Graduate Study

A graduate of an accredited college or university may be considered for admission to the Graduate School. The decision to admit a student ordinarily rests with the applicant's major department and stands for one year following the first semester for which admission was offered. If more than one year elapses, the prospective student's department reserves the right to reconsider the original offer.

Applications for admission may be obtained by writing to the Graduate Admission Office, Whitaker Laboratory 5, Lehigh University, Bethlehem, Pa. 18015.

An applicant may enter the graduate program as a student in one of two categories: regular or associate. Except for qualified Lehigh undergraduates, only those who have been admitted officially by the graduate admission office either as regular or associate graduate students may register for graduate courses or take them for credit.

**Regular graduate students.** Only regular graduate students are candidates for graduate degrees. Application for admission as a regular graduate student must be filed by July 15 for the following fall semester or by Dec. 1 for the spring semester. Regular applications for the first and second summer sessions are accepted until April 30 and May 30 respectively. In order to be considered for admission as a regular graduate student, the applicant must satisfy at least one of the following conditions: have an undergraduate G.P.A. of at least 2.75 out of 4.00; have an average of at least 3.00 for the last two semesters of undergraduate study; have scores at or above the 75th percentile on the Graduate Record Examination or other recognized test (all foreign graduate students are required to take the Test of English as a Foreign Language and achieve a minimum score of 550); have a graduate grade-point average of at least 3.00 for a minimum of twelve credit hours of graduate work completed at other institutions; or have successfully satisfied the probationary conditions as an associate graduate student discussed below. Satisfying one of these conditions is a necessary but not sufficient condition for admission as a regular graduate student.

Individual departments may evaluate their candidates for admission according to higher standards and additional criteria. Departments should be consulted for information regarding required examinations for admission. For example, candidates for the M.B.A. program are required to take the Graduate Management Admission Test (GMAT).

**Associate graduate students.** Associate graduate student status may be offered to applicants who apply but fail to qualify for regular graduate student status. Only associate student applications will be considered during the late admissions period between the end of the regular admission period and the first day of classes. Applicants for associate status may submit unofficial rather than official transcripts; letters of recommendation are not required at that time. The Registrar will require an official final transcript, however, before grades are released.

Associate graduate students who are admitted during the late admission period and who clearly qualify for admission as regular graduate students may petition for regular status after classes begin if all credentials are in order. There is no late application fee.

Other associate graduate students must meet the following condition before they may petition for regular status: completion of the first nine credit hours of courses numbered 300 or higher with at most one grade of C, C+, or B−; all other grades must be B or better. Students receiving a grade of C− or lower will be dropped from the program. Students should note that individual departments may impose more rigorous probationary standards.

When the probationary period of nine credit hours is completed successfully, associate graduate students must petition for regular student status in order to continue. This requires the submission of regular admission documents not already on file. Courses completed during a successful probationary period may count toward a graduate degree if they are part of an approved program.

**Lehigh University undergraduates.** A Lehigh undergraduate may take any 400-level course for which he or she is qualified. The qualifications are defined by the department, and are certified by the course instructor and department chairperson through petition to the graduate committee.

Undergraduates at Lehigh who are within a few hours of meeting the requirements for a baccalaureate degree may, with the special approval of the graduate committee, enroll for a limited amount of study for graduate credit. Lehigh undergraduates may apply course credits taken in the undergraduate program toward a graduate degree under the following conditions: (a) the course credits are not submitted as part of the requirement for an undergraduate degree; and (b) courses for possible graduate credit are approved in advance by the course instructor, department chairperson, and the dean of graduate studies. The student must receive a grade of B− or better.

**Readmission.** A student who has not been registered in a Lehigh graduate program for five years must petition for readmission. Petitions approved by the student's major department must be forwarded to the graduate admission office.

**International Students and Scholars.** The Office of International Students and Scholars is located in Room 344, Whitaker Laboratory 5. Please refer to page 22 of the catalog for additional information.

# Registration

**Requirements.** All graduate students using Lehigh University resources must be registered. No graduate student may register for more than 15 credits per semester. University employees may register for, at most, two courses per semester with appropriate approval. The maximum registration in a summer session is six credits.

**Full-time status.** In order to maintain full-time enrollment status, a graduate student must ordinarily register for a minimum of nine credits each semester. Identification as a full-time student is important for three purposes: (1) eligibility for financial aid, (2) compliance with visa requirements for international students, and (3) for university and national graduate enrollment data.

After fulfillment of degree credit-hour requirements and in some other circumstances, full-time status may be maintained with fewer than nine credits of registration, provided that the student is, in fact, continuing a program of full-time study and research. In such cases, the status must be certified on the Graduate Registration form, first by the department and then by the Dean of Graduate Studies.

**Registration procedure.** Graduate registration is held during the week preceding the start of classes. Students should check with their departments for registration and semester class schedules. To register, graduate students must complete registration forms and personal data sheets available in their departments. A course adviser will discuss course selections with students and sign registration forms upon approval.

**Late registration penalties.** Registration between the second and tenth day of class during the fall and spring semesters, and the second and fifth day of class during the summer sessions will require a late registration fee. Students who have not completed the registration process by the tenth day of the regular academic semester or by the fifth day of the summer session will not be permitted to attend class.

**Services provided by the registrar.** In addition to maintaining student academic files, the office of the registrar fills transcript orders. The registrar honors written and over-the-counter requests to have transcripts mailed to schools and prospective employers.

The office also forwards final grades to students approximately two weeks after each final exam period, provided student credentials are in order.

# Graduation

**Degree registration.** A student must be registered in the semester in which the degree is conferred. A spring or summer registration will satisfy the registration requirement for the following Founder's Day degree, provided all work is completed before the first day of fall classes.

**Application for degree.** Candidates for degrees to be conferred on University Day in May or June must file an application for degree with the registrar by March 1. Candidates for degrees to be conferred on Founder's Day in October must file this form by September 1. Candidates for degrees to be conferred in January must file by December 1. Late application for a degree will incur a penalty fee of $25.

**Clearance.** Graduate students must receive clearance from the university prior to the awarding of the degree. The following obligations must be satisfied:

- Students must be certain that they have completed all coursework for incompletes they may have received.
- Theses and dissertations must be cleared by the Graduate School office.
- All financial obligations must be cleared with the bursar. Tuition fees, bookstore charges, library fines, and motor vehicle fines must be paid before graduation.
- All library books on loan must be returned.
- Students must turn in their student identification cards at Christmas-Saucon Hall Annex.
- The interdepartmental clearance sheet must be completed. This form requires the signature of the student's department chairperson (except for the College of Education), and the facilities services office before it is submitted to the registrar at least three days prior to graduation.

# Tuition

**Tuition payment.** Graduate students must register for courses and pay tuition bills at the bursar's office during the registration period held the week before classes begin. Students who mail their registration forms, personal data sheets, and tuition payments to the bursar's office must be certain that their forms are postmarked by the final day of the registration period.

**Tuition refunds.** A student in good standing who formally withdraws from a course during the first eight weeks of the semester or reduces the course enrollment below twelve credit hours after the first two weeks is eligible for a tuition refund. The refund schedule for student withdrawals and course adjustments is as follows:

| | |
|---|---|
| prior to the start of the semester | 100% |
| during first calendar week | 80% |
| during second calendar week | 70% |
| during third calendar week | 60% |
| during fourth calendar week | 50% |
| during fifth calendar week | 40% |
| during sixth calendar week | 30% |
| during seventh calendar week | 20% |
| during eighth calendar week | 10% |

Students should note that the first calendar week begins with the first day of classes at the university.

## *Tuition and Fees for 1989-90*

| **Full-time students** (12 or more credit hours) | **per semester** | **per year** |
|---|---|---|
| Tuition | $6,775 | $13,550 |
| Per-credit-hour charge | 565 | |
| Per course charge for audit | 565 | |
| Per-credit-hour charge for enrollees in the College of Education and for full-time elementary and secondary teachers and administrators enrolled in the other three colleges | 295 | |
| Research and graduate assistants (charge for 9-10 credit hour semester registration) | 4,515 | 9,030 |
| Maintenance of candidacy | 565 | |
| Master's candidate registration fee | 565 | |

**Living accommodations.** The university maintains a graduate student housing complex in the Saucon Valley that has 112 living units. This complex, Saucon Village Apartments, provides units generally on a yearly lease basis. For the 1989-90 period beginning in September, the following monthly rents exclusive of utilities prevail:

| | |
|---|---|
| Efficiency apartment | $315 |
| One-bedroom apartment | 375 |
| Small two-bedroom apartment | 415 |
| Two-bedroom apartment | 420 |
| Three-bedroom apartment | 435 |

### *Other Fees*

| | |
|---|---|
| Application fee (for graduate admission consideration) | $40 |
| Graduate activities fee, per semester | |
| Full-time students | 12 |
| Part-time students | 6 |
| Late registration (for completing registration after announced day) | 50 |
| Late application for degree | 25 |
| Late payment (after announced date) | 50 |
| Late processing fee | 50 |
| Return check fine | 20 |
| Identification card (replacement) | 10 |
| Thesis, microfilming | 25 |
| Dissertation, microfilming | 50 |
| Placement fee, College of Education | 25 |
| Supervision fee, College of Education (per 3 credits) | |
| Counselor intern | 100 |
| Counselor and school psychology clinic | 100 |
| Social restoration intern | 225 |
| Reading practicum | 100 |
| Administrative intern | 225 |
| Elementary and secondary intern | 225 |
| Special education intern | 225 |

## Financial Aid

Financial aid is ordinarily available only for regular, full-time graduate students. Teaching assistantships, research assistantships, graduate assistantships, fellowships, and scholarships are academic awards made by individual academic departments or by the Graduate School. Several graduate assistantships unrelated to a particular area of study can be obtained by applying to administrative offices. Finally, loans and work-study employment are distributed by the Office of Financial Aid.

**Academic awards.** Requests for fellowships, scholarships, research assistantships, teaching assistantships, and graduate assistantships to begin in the fall semester must be filed with academic departments no later than February 1. Generally, a special committee formed by department faculty selects the recipients of these awards based upon merit; students are not required to submit a financial statement.

In addition to their stipends, graduate students holding half-time teaching appointments generally receive tuition remission. Fellowship holders also receive a stipend and tuition award. Scholarship recipients are awarded tuition. Research assistants receive a stipend for research services, but their tuition is commonly paid directly by research projects.

**Teaching assistants and graduate assistants.** Teaching assistant and graduate assistant (T.A./G.A.) are technical terms used to describe specific types of Lehigh University student employees. The duties of T.A.s and G.A.s are generally set by the departments or offices that employ them, but certain conditions must be satisfied before a student can be classified as a teaching assistant or a graduate assistant. These include:

- Each T.A./G.A. must be a regular full-time resident Lehigh graduate student, which normally requires registration for at least nine credit hours per semester.
- A T.A./G.A. is a half-time position and each T.A./G.A. provides services to Lehigh University of up to twenty hours per week. Quarter-time and eighth-time T.A./G.A. appointments are possible for full-time resident graduate students, with stipends and tuition remission appropriately reduced.
- Each T.A./G.A. must be paid a specific stipend, which is set for the academic year by the dean of graduate studies after consultation with the director of budget.
- Qualified T.A.s/G.A.s receive tuition remission for at most ten credit hours in a regular semester. No T.A./G.A. may register for more than ten credit hours. A student who is a T.A./G.A. during the preceding academic year is entitled to at most three hours of thesis, research, or dissertation registration (not course credit) in the following summer without payment of tuition.
- Each T.A./G.A. is appointed by a process which begins with a formal letter of appointment issued by the appropriate department chairperson. The appointment letter specifies standard university conditions including stipend level, time of arrival, length of service, and the requirement of satisfactory academic progress and performance of duties. Each department chairperson submits written notification of T.A./G.A. appointments to the appropriate college dean or vice president.

The graduate committee endorsed academic guidelines for new teaching assistants which exceed minimum admission requirements. Each T.A. should satisfy one of the following: have a G.P.A. of 3.0 or better in the undergraduate major field of study; have a G.P.A. of 3.5 in the senior year major field; rank in the 85th percentile or higher on the Graduate Record Exam or other standardized test; or have a G.P.A. of 3.5 in at least twelve hours of graduate work in the major field. Exceptions to these guidelines shall be made only with the approval of the dean of graduate studies.

In addition, each teaching assistant must make normal progress toward a graduate degree. The definition of normal progress may vary among departments, but the criteria for satisfactory progress are established by the department faculty and the graduate committee. Teaching assistants who fail to satisfy these criteria are ineligible for reappointment.

Teaching assistants whose native language is other than English must have on record with the ESL Program a comprehensibility score of 230 or higher on the SPEAK (Speaking Proficiency English Assessment Kit) or the TSE (Test of Spoken English) in order to work with Lehigh undergraduates in academic settings (i.e., classrooms, recitations, labs, office hours, etc.).

Those whose comprehensibility score is 220-229 may also be appointed as T.A.s, but they are required to attend ESL courses until their comprehensibility score is at least 230 or until they no longer have a T.A. position. A comprehensibility score of 200 or below eliminates an international graduate student from being appointed as a T.A.

The SPEAK is given at announced times during the academic year, usually at the beginning and end of each semester. Contact the ESL Program (401 Coppee Hall, ex.84439) for details and for information concerning ESL courses. The TSE is given by ETS several times each year throughout the world.

- Tuition remission for qualified T.A.s/G.A.s is authorized by the appropriate dean or vice president as part of the registration process.
- Each college dean or appropriate vice president will be provided tuition remission accounts against which T.A./G.A. remissions will be charged. The accounts will be budgeted at an amount equal to the ten-hour T.A./G.A. tuition rate times the approved number of T.A./G.A. positions included in the annual operating budget. The budgets shall not be exceeded. If additional T.A./G.A. positions are desired on a temporary basis, the account executive must provide for the transfer of budget support to the remission account. These budgets are to be used exclusively for tuition remission for authorized T.A./G.A. positions.

There are a limited number of summer T.A./G.A. appointments. These T.A./G.A. employees must receive the same monthly stipend as academic year T.A.s/G.A.s and provide services of up to twenty hours per week to the university. A summer T.A./G.A. registers for a maximum of three credit hours in each summer session of employment and receives tuition remission for that registration.

**Other graduate assistantships.** Graduate students may apply directly to administrative offices for graduate assistantships unrelated to their areas of study. The availability of these assistantships is based upon the needs of the individual departments. G.A.s are employed regularly by the graduate school office, the office of the vice president of student affairs, the dean of students office, the university counseling service, and by career services.

**Loans and work-study awards.** Students may apply for Perkins Loans, Lehigh University Tuition Loans (UTL), and College Work-Study (CWS) through the Office of Financial Aid, located at 218 West Packer Ave. These aid sources are awarded on the basis of financial need as determined by the Office of Financial Aid, utilizing the Financial Aid Form (FAF) and the federally approved Congressional Methodology. The FAF and the Lehigh application must be accompanied by the most recent copy of both the student's federal tax return, and in some cases, by that of his or her parents. Financial Aid Transcripts (FAT) are required from all post-

secondary institutions attended before (1) funds may be disbursed or, in the case of GSL and Supplemental loans, (2) applications can be certified. This is a federal requirement.

**Perkins loans** subject to the availability of funds, may be awarded to full-time students (nine or more hours per semester). Interest is at 5 percent per annum, with quarterly repayments commencing six months after graduation or withdrawal. Total Perkins borrowing cannot exceed $18,000 for both undergraduate and graduate study.

**University tuition loans** may be awarded in amounts up to $5000. Current interest rate is 9 percent; interest rate is subject to change. Repayment commences 90 days after graduation or withdrawal from the university, in monthly installments (minimum of $50) plus interest until repaid in full.

**College work-study (CWS),** subject to the availability of funds, may be awarded to graduate students. The university pays on an hourly rate basis. All sources of aid, including CWS, cannot exceed the student's computed financial need.

**Frank Brady loans** are made from an endowed fund that permits loans of up to $2,500 to be awarded to students enrolled in the MBA program. Applications are filed initially with the department of accounting. Subject to the approval of the chairperson of that department, the applicant completes the final application with the Office of Financial Aid. Brady loans are made without regard to financial need. Interest rates are subject to change. Contact the Office of Financial Aid for the current rate.

**U.S. Steel Foundation loans** are administered by the dean of Graduate Studies. Loans of up to $2,500 may be requested, with the interest at the rate of two percent per annum. Repayment of the principal will be at the rate of $1,000 per year or 25 percent of the loan, whichever is less. The installment and interest will be paid on each anniversary of the student's termination of residency. Loans may be awarded to qualified graduate students in the engineering, and physical sciences, or business. Financial need, as determined by the dean, is a prerequisite for consideration.

**Robert T. Stafford loans** (formerly the Guaranteed Student Loans) are granted by commercial lenders. Students may borrow up to $7,500 per year of full-time enrollment (or $3,750 for half to three-quarter time enrollment). Eligibility will be affected by (1) level of enrollment (2) other financial aid received, and (3)level of income. Detailed brochures are available in the Office of Financial Aid or at participating lenders. Students having borrowed as undergraduates should continue to borrow from their previous lender. Interest is currently 8 percent per annum, with repayment in monthly installments commencing six months after graduation or less than half-time enrollment. The lender deducts a 5 percent loan origination fee from the proceeds of the loan. Nonsubsidized loans are available to Lehigh students through the PHEAA program.

**PHEAA Supplemental Loans** are available to Lehigh students, with borrowing limits to a maximum of $10,000 per year for full-time study. Supplemental Loans require a co-signer and are based on a credit check to determine eligibility. Current interest rate is at 9.5 percent. Repayment is expected to begin immediately and to extend over a ten-year period. Alternative repayment plans include, upon approval of PHEAA, (1) payment of interest only on a quarterly basis, (2) make no payments of principal or interest while enrolled, with interest accruing and added to the outstanding principal semi-annually.

Pennsylvania residents, with or without prior GSLs outstanding, can use the PHEAA-HELP application to apply for either the interest-subsidized (or, if not eligible, the nonsubsidized) Guaranteed Student Loans and the Supplemental Loans. Applications are available from most participating GSL lenders.

Nonresidents who have borrowed under GSL previously must continue their GSL borrowing with their lender. Applications for the Supplemental Loan can be obtained from lenders in the Bethlehem area of from the Office of Financial Aid. Nonresidents with no prior GSLs can apply for both forms of GSL and the Supplemental Loan through Bethlehem area lenders.

**Graduate Supplemental Loans** for students are available on a non-need basis to supplement any of the above, so long as all aid sources do not exceed the cost of education. Loan limits per year are $4,000 for full-time study and $2,000 for half-time enrollment. Loans are granted on the basis of having established a good credit rating and being financially able to repay the loan. A qualified endorser may be required. The current interest rate is 10.3 percent per annum. Many GSL lenders are also SLS lenders.

A student's official classification with the registrar governs the way in which the loan coordinator for the Office of Financial Aid must certify the loan application. Anyone listed as an associate graduate student is, by definition, not a degree-candidate graduate student and does not qualify to borrow at the graduate student rate of $7,500 per year for full-time study. Associate students are limited to $4,000 for full-time study and $2,000 for half-time enrollment, further affected by whether or not they received loans as fifth-year undergraduates. Questions may be directed to the loan coordinator.

# Degree Information

The following degrees are offered by the Graduate School: the master's degree, the doctor of philosophy, and the doctor of arts.

## *Master's Degree*

Candidates for the master's degree have six years in which to complete their programs. Students should confer with their advisers to be certain that specific department and program course requirements are met. The following requirements must be satisfied by master's candidates in all departments.

**Program for the master's degree.** A student's program must include: not less than 30 credit hours of graduate work: not less than 18 credits of 400-level coursework (research or thesis registration counts as part of the 400-level coursework requirement); not less than 18 credits of coursework in the major of which 15 credits must be at the 400 level. All coursework for the master's degree must be taken under at least two instructors and must normally be done in attendance at Lehigh University. With the approval of the Dean of Graduate Studies, a maximum of six credits may be transferred to a Lehigh Master's program. A petition is submitted, with course descriptions and transcript, as well as departmental recommendation. Course grades of B or better are required.

A student must complete the form, program for master's degree, setting forth the courses proposed to satisfy the degree requirements. This form should be approved by the department and then submitted to the Graduate School as soon as possible after 15 credit hours toward the degree have been completed. Approval of the program by the Graduate School signifies that the student has formally been admitted to candidacy for the master's degree.

**Thesis and comprehensive exam.** Candidates are required to submit a thesis or a report based on a research course of at least three credit hours, or to pass a comprehensive examination given by the major department. The department will specify which of these requirements applies and may require both. If required, the thesis or report shall not count for more than six credit hours. University procedures must be followed if the thesis or research project involves human subjects. One unbound copy of the thesis, approved by the thesis adviser and the department, must be delivered to the Graduate School at least three weeks before the degree is conferred. A binding and microfilming fee of $25 must be paid to the bursar, and the bursar's receipt presented with the completed thesis. Guidelines stipulating the form of the thesis are available in the Graduate School office.

## *Doctor of Philosophy*

**Time and Registration requirements.** A candidate for the doctor of philosophy degree is expected to devote at least three academic years to graduate work. All post-baccalaureate work toward the doctorate must be completed within ten years. A student beginning doctoral coursework after an elapsed period of at least one semester after the master's degree has been conferred is granted seven years in which to complete the doctoral program.

Doctoral students whose graduate study is carried out entirely at Lehigh University must register for a minimum of 72 credits beyond the Bachelor's degree. However, resident students who during their entire doctoral program, including the semester of graduation, have paid full tuition continuously (normally a minimum of 9 credits per academic semester) will have satisfied the tuition requirements for the doctoral degree upon completion of all other requirements. Students who have earned a master's degree at another university must register for a minimum of 48 credits. These requirements include registration for research of dissertation credits.

Full-time students working toward the doctorate normally register for a minimum of nine credits each semester. If the minimum degree registration requirement of 72 or 48 credits is attained prior to formal admission to doctoral candidacy, continued registration of at least three credits per semester is necessary. Full-time student status must be certified on the graduate registration form.

After admission to doctoral candidacy, a student must maintain candidacy by registering at least two times each calendar year (in each academic semester or in one academic semester and one summer session). After completion of the minimum registration requirement plus any additional requirements of the student's department or program, registration is permitted for 'Maintenance of Candidacy.' The tuition charge is for one credit-hour. Full-time status again must be certified on the graduate registration form.

**Residence.** Each Ph.D. candidate must satisfy Lehigh's residence requirement. The residence requirement is intended to ensure that doctoral students spend a period of concentrated study and intellectual association with other scholars. Either two semesters of full-time graduate study or 24 credit hours of graduate study within a twelve-month period must be completed.

Individual departments may impose additional stipulations. Candidates should check with their advisers to be certain that they have satisfied their residence requirements.

**Language requirements.** Language requirements for the Ph.D. are the option of and in the jurisdiction of the candidate's department. Since proficiency in a language is not a university requirement, each department decides which languages, if any, constitute part of the doctoral program.

**Qualifiers.** Many departments require students who wish to enroll in doctoral programs to pass qualifying examinations. Since these examinations vary among departments, students should ask their advisers or department chairpersons for more detailed information. If a qualifying examination is not used, students should find out how and when eligibility to pursue doctoral studies is determined.

**Admission to candidacy.** With the help of an academic adviser, the student names the faculty members of the doctoral committee, a special committee formed to guide the student through the doctoral program. The committee is responsible for assisting the student in formulating a course of study, satisfying specific departmental requirements, submitting a suitable dissertation proposal, overseeing progress in research, and evaluating the completed dissertation. At least four faculty are appointed to the committee; one must be a member of an outside department. Committee membership must be approved by the university's graduate committee.

A doctoral student should apply for candidacy no later than one year after completion of the master's degree or its equivalent and after passing qualifying examinations if they are required by the major department. The prospective Ph.D. candidate must submit to the doctoral committee a written program proposal that includes a discussion of proposed dissertation research. Upon receiving approval of the proposal, the candidate submits the proposal, signed by the committee members, to the graduate school for action by the graduate committee. The dean will advise the student of the graduate committee's decision.

If the dissertation research involves human subjects, university procedures must be followed.

**General examinations.** Examinations composed and administered by the members of the student's doctoral committee are designed to test the candidate's proficiency in a particular field of study. These examinations, which may be both written and oral, should be passed at least seven months before the degree is to be conferred. If a student fails the general examination, a second examination will be scheduled not earlier than five months after the first. If the results of the second examination are unsatisfactory, no additional examination is scheduled.

**Dissertation and defense.** The Ph.D. candidate is required to write a dissertation prepared under the direction of a Lehigh University professor. The dissertation must treat a topic related to the candidate's specialty in the major subject, show the results of original research, provide evidence of high scholarship, and make a significant contribution to knowledge in the field.

Upon approval of the advising professor and, if required by the department, secondary readers, the dissertation is submitted to the dean of graduate studies for inspection at least six weeks before the degree is to be conferred. Upon its return, the student should distribute copies of the draft to the members of the doctoral committee for review and for suggestions for revision. The candidate then schedules a dissertation defense before the doctoral committee, additional faculty members the department may add to the examining committee, and the general public. The date of the examination is sent in advance to the dean of graduate studies.

After the dissertation has been defended and revised accordingly, the student must submit the finished dissertation to the dean of graduate studies for review by the university's graduate committee no later than two weeks before the degree is to be conferred. Two unbound copies must be delivered to the Graduate School office. One copy must bear the original signatures of the special committee members. In addition, the candidate must pay a microfilming fee of $50 and present a bursar's receipt for the payment. Guidelines stipulating the standard form of the dissertation are available in the Graduate School Office.

### *Doctor of Arts (D.A.)*

The doctor of arts degree (D.A.) is offered to students preparing for careers in college teaching in the field of chemistry. The program requirements are similar to those for the Ph.D. with the following exceptions: (1) a broader distribution of graduate courses in the field, (2) a minor area of study for students interested in bidisciplinary preparation for two-year college teaching, (3) coursework and training in interpersonal awareness, (4) a supervised internship in college teaching, (5) and a research project appropriate to college teaching in the student's field of specialization.

## Graduate Degrees in Business Administration and Economics

Candidates for admission to graduate study in the College of Business and Economics must provide the results obtained in either the Graduate Management Admission Test (GMAT) for degrees in business administration, or the Graduate Record Examination general test (GRE) and the subject test in economics for degrees in economics.

### *Master of Business Administration*

The Master of Business Administration (MBA) degree program is designed to provide candidates with conceptual, analytical, and operational skills that are involved in the decision-making processes connected with managing human, physical, and financial resources. The MBA curriculum provides a blend of strong theoretical foundation together with practical application in the areas of accounting, behavioral, economics, finance, the legal environment, management, marketing, and quantitative methods.

Education in the business professions requires understanding the various organizational functions and integrating these with internal and external aspects of the enterprise into the managerial process. The program encompasses generalized managerial competence, while permitting advanced concentration in such fields of specialization as finance, marketing, quantitative and behavioral facets of management, accountancy, economics, international trade and finance, and labor and industrial relations.

All candidates for entry into the MBA program are required to take the Graduate Management Admission Test (GMAT). Information concerning this test may be obtained at college and university counseling centers, or by contacting GMAT, Educational Testing Service, P.O. Box 6103, Princeton, N.J. 08541-6103.

**Program prerequisites.** Students entering the MBA program should have completed college-level coursework in principles of economics, calculus, and computer literacy. Although failure to complete these prerequisites will not necessarily result in denial of admission to the program, a student without them will be expected to complete the three prerequisites at Lehigh or elsewhere by the end of the first semester following matriculation into the program. If a student can demonstrate proficiency in a high-level programming language without formal coursework, he or she may petition to have the computer programming prerequisite waived.

**The MBA curriculum.** The minimum number of credit hours required for the MBA degree is thirty, normally consisting of ten

courses. This minimum presumes that the foundation courses in the various functional fields were completed prior to entry into the MBA program. (A person who received a baccalaureate degree in business administration from an accredited institution may reasonably expect to have fulfilled the foundation course requirements, discussed in further detail below). This thirty-hour program may be completed in two semesters by taking fifteen credit hours each term, or by taking twelve credit hours each semester plus six during the summer sessions, or some other combination. The following four courses are required in this 30-hour format:

| | |
|---|---|
| Acct 421 | Information Systems for Managers |
| Econ 421 | Managerial Economics |
| Mgt 423 | Operations Management |
| Mgt 429 | Managerial Policy and Decision-Making |

In addition, six 400-level elective courses are to be selected from at least four functional areas, with no more than two courses being taken in any single area. A maximum of two of these six electives may be taken in academic departments at Lehigh outside the College of Business and Economics with prior permission of the MBA director and respective department chairperson. These other departments include (among others) Computer Science, Industrial Engineering, Psychology, and Social Relations.

For the candidate who has not completed one or more of the first ten foundation courses listed below; up to a maximum of forty eight credit hours is required in the MBA program. However, up to six required foundation courses may be waived outright upon the candidate providing evidence of satisfactory completion of equivalent coursework, or passing a proficiency examination in that subject area. In addition, four foundation courses are subject to limited waiver, with advanced courses being required as replacement-electives. The required coursework is:

| | |
|---|---|
| Acct 403 | Financial Flows and Accounting Measurements* |
| Acct 413 | Managerial Accounting and Decision-Making** |
| Econ 401 | Basic Statistics for Business and Economics* |
| Econ 408 | Price Theory and Application* |
| Econ 409 | Money, Banking, and Macroeconomic Analysis* |
| Fin 411 | Financial Management** |
| Law 404 | Legal Environment of Management* |
| Mgt 401 | Quantitative Methods in Business and Economics* |
| Mgt 413 | Organizational Behavior and Management** |
| Mkt 413 | Marketing Management** |
| Acct 421 | Information Systems for Managers |
| Mgt 423 | Operations Management |
| Mgt 429 | Managerial Policy and Decision-Making |

In addition, three 400-level elective courses are to be selected, with no more than two courses being taken in any single area.

* Waiver policy: This course may be waived if a comparable course or courses (see the course-description section of this catalog) was taken with a grade of B− or better being earned not more than eight years prior to matriculation into Lehigh's MBA program.
** Limited waiver policy: This course may be waived depending on prior coursework and academic performance as determined on a case-by-case basis in consultation with the MBA director and respective department chairperson in accordance with guidelines established by the faculty. If the course is waived, an advanced graduate-level course in the same area may be required to be taken as one of the MBA elective courses.

### *Master of Science Degree in Business and Economics*

The master of science degree is offered to students interested in pursuing graduate work in economics or in economics and business.

A minimum of thirty semester hours of coursework is required. At least eighteen of these hours must be taken in the College of Business and Economics. In addition, the student will be expected to pass comprehensive examinations in general economic theory and in one other field in the college.

To qualify for the master of science degree, the student must also take Eco. 352, Advanced Statistical Methods, and Management 401, Quantitative Methods, as part of his or her thirty semester hours of coursework.

### *Master of Science Degree in Management Science*

This degree is available to students as an interdisciplinary degree. More information is provided on p. 52 in the College of Business and Economics. The master of science in the management science program is directed toward integrating the scientific method with the functional aspects of organizations. By investigating the application of quantitative methodology and systems analysis in the context of such areas as accounting, applied economics, finance, marketing, production, and public service, the program helps to develop a meaningful analytical perspective of business problems.

This integration provides the student with a broader perspective of managerial decision making in private enterprise and/or public administration. Students who have had prior exposure as undergraduates to engineering, business, economics, mathematics, or the physical sciences and who desire a quantitatively oriented business program are ideal candidates.

Management science graduates may pursue careers as staff specialists or as line managers who must deal with the increasingly complex problems of industrial, commercial, and public service organizations.

At the completion of the degree requirements, the student will have acquired an excellent background in the various functional areas of business and economics. Included is a three-credit research project or practicum aimed at providing the student with professional exposure while still in a formal educational environment. Each student conducts an empirical investigation of an actual management problem and submits an individual written report.

### *Doctor of Philosophy*

The Ph.D. degree in business and economics is designed to provide advanced knowledge and the capacity to carry on independent research in various areas of business and economics. Holders of the Ph.D. are normally employed in academic positions in departments of economics or in schools of business administration, or in policy analysis and research positions in banks, business, government, and research organizations. Employment opportunities are excellent for holders of this degree.

The Ph.D. program requires a minimum of 48 semester hours of study (including dissertation) beyond the master's degree or 72 hours of study beyond the bachelor's degree. Each student is expected to choose three major and two minor fields of specialized study. Economic theory must be included as one of the major fields. Each student must take a research core of twelve hours and prepare for written and oral comprehensive examinations in the major fields. The chairperson of the doctoral committee will help to arrange a plan of study suitable for each student's program and to prepare the student to pass the examinations.

Major and minor fields of specialization that are normally available include economic theory, international economics, labor economics, managerial economics, money and banking, private finance, and public finance. Minor fields include accounting, marketing, organizational theory, business law, and other related areas in the college or university.

Under the guidance of a dissertation chairperson and committee formed after passing of the examinations, the candidate undertakes research culminating in an acceptable dissertation. The Ph.D. is awarded upon the successful completion of the doctoral dissertation and its oral defense.

## Graduate Degrees in Education

Lehigh's College of Education offers only graduate degree programs. Students enrolled in the College of Education should check with their

adviser for a list of regulations and requirements governing their degree programs.

**Financial assistance.** The College of Education, because it does not offer many undergraduate courses, cannot provide teaching assistantships for graduate students. Graduate assistantships and research assistantships are available in the College and in various administrative offices on campus. In addition, graduate students may be recommended for a limited number of fellowships and scholarships, which are awarded by the dean of graduate studies.

Lehigh's Centennial School, a laboratory school for socially and emotionally disturbed children, provides employment for some Lehigh education students. Graduate students may apply for teaching internships, which pay tuition plus salaries.

### *Master of Education (M.Ed.)*

This degree is offered in the following professional specializations: elementary education, secondary education, special education, educational administration, community counseling, elementary and secondary school counseling, reading, and social restoration. Degree requirements vary from program to program.

### *Master of Arts (M.A.)*

The master of arts degree offered in the field of secondary education provides a major in education with an academic specialty. The student must take eighteen credits of graduate work in education plus twelve credits of graduate work in an academic field. The academic fields that cooperate with the College of Education in offering this program include: classical languages, modern foreign languages, English, mathematics, economics, government, social relations, history, international relations, or physical and natural sciences.

### *Master of Science (M.S.)*

The master of science degree is awarded in educational technology.

### *Educational Specialist (Ed.S.)*

Specialized post-master's degree programs for practitioners are available in school psychology, special education, and various programs for supervisors.

### *Certification and Concentration Programs*

In addition to offering master's degrees, the College offers state certifications in various professional specialties. The College of Education also offers special twelve to fifteen credit programs that provide concentrations in gifted education and education of the severely/multiply handicapped.

### *Doctor of Education (Ed.D.)*

The doctor of education degree program provides specialized study in elementary education, special education, educational administration, counseling, reading, foundations of education, and educational technology. Successful professional experience is required for admission to candidacy for this degree in most programs.

The requirements for the Ed.D. degree parallel those already stated for the Ph.D. degree with the following exceptions: language examinations are not required; and a statistics competency examination is required. The residence requirement for the Ed.D. is the same as that for the Ph.D.

### *Doctor of Philosophy (Ph.D.)*

The College of Education also offers the Ph.D. degree to students enrolled in the fields of school psychology, special education, and counseling psychology.

## Graduate Study for Engineering Professionals

All departments within the College of Engineering and Applied Science offer a cooperative program that allows an engineer working in industry to further his or her education while retaining a professional position. Students enrolled in this program may pursue an M.S., M.Eng., or Ph.D. at Lehigh while employed full-time, completing the course requirements for the degree in a period of time that does not greatly exceed that spend by full-time graduate students in residence at Lehigh.

A professional interested in participating in this program applies to the Graduate School through a participating department. (See course listing for each department for specific areas of research, courses available, and departmental requirements.) When accepted, he or she chooses the track best suited to his or her individual needs. Each track allows a student to obtain a master's degree; then, a highly motivated professional may pursue a doctoral degree if he or she chooses.

In any case, however, the residency requirements for the master's degree are fulfilled by spending two semesters at Lehigh as a resident graduate student. During the intervening semesters or summers, the student returns to the full-time, professional position. (It is best to spend a fall semester and spring semester on campus to allow maximum flexibility in course selection.)

The thesis or project required for the degree sought is decided upon through mutual consultation among the student, the adviser at Lehigh, and the supervisor in industry. The thesis or project work is begun during the student's first semester at Lehigh with the body of work performed when the student returns to his or her position in industry. Then, the thesis is completed when the student returns to Lehigh.

Each student chooses a faculty member at Lehigh who serves as academic adviser, helps the student select appropriate courses, and oversees the thesis or project work. The student also has a corporate adviser, preferably the person to whom the student reports, or a senior experienced member of the corporate staff. It is hoped that in many cases the interactions among faculty member, corporate adviser, and student/employee will form the basis for a continuing relationship between the university and industry that will allow significant and ongoing research areas to be addressed by a sequence of students seeking advanced degrees.

While enrolled in the program, the student remains an employee of the company or corporation and receives his or her salary as usual. (Lehigh considers that salary a matter to be arranged between the student and the employer.) Students are responsible for the full tuition due the university and are reimbursed by their employers according to company policy. Generally this means that students must make satisfactory progress towards the degree sought and achieve acceptable grades in coursework.

Because the program requires additional work by faculty and staff, the company agrees to donate a sum equal to the university's tuition to the department in which the personnel are enrolled. In addition, companies agree to assist the department in meeting laboratory, computer, and other research costs that accrue during the student's research or project work.

The program is structured to be flexible enough to meet the needs of professional participants; the choice of approach will depend on the circumstances that pertain to particular industries and to the needs and interests of individual students.

A brochure describing this program in detail is available from the College of Engineering and Applied Science, Packard Laboratory 19, Lehigh University, Bethlehem, Pa. 18015.

## Graduate School Organizations

### *The Graduate Committee*

The graduate committee consists of the dean of graduate studies and twelve members representing the faculties of Lehigh's colleges: four from the College of Arts and Science; two from the College of Business and Economics; four from the College of Engineering and Applied Science; and two from the College of Education. In addition,

four graduate students may attend committee meetings as non-voting member. A current graduate committee membership list is available in the graduate school office.

The committee is instrumental in formulating educational policies on issues such as graduate admission procedures, curriculum, and administrative regulations. These recommendations are eventually passed on to the University faculty for approval.

The graduate committee interprets graduate educational policies. The committee has independent executive power with regard to graduate petitions. In order to provide a forum for complaints regarding academic and non-academic matters, the graduate committee will schedule hearings for individual graduate student grievances. Students may petition, via the dean of graduate studies, for extensions of time to complete degrees and for reinstatement to programs. Students denied admission to the graduate school, even though they are not members of the university community, may also present petitions to the graduate committee.

### *Graduate Alumni Committee*

The Lehigh University Alumni Association has established a graduate alumni committee. The committee is composed of distinguished Lehigh graduate alumni and is chaired by Michael H. Danjczek, M.Ed. 1974, Ed.D. 1987, the director of the Easton Children's Home. The committee will provide leadership deepening the involvement of graduate alumni in Lehigh affairs.

### *Graduate Student Council*

The graduate student council, comprised of one graduate student from each academic department, represents the graduate student community regarding graduate programs and graduate student life at Lehigh. It provides a forum for discussion with university officials and committees. Graduate students selected by the graduate student council are non-voting members of the graduate committee and the educational policy committee. In addition, four graduate student council members serve on the dean's advisory committee in order to provide a liaison between the dean of graduate studies and the graduate student council.

Besides functioning as a forum for discussion, the graduate student council maintains a graduate student center. The council plans social events and disseminates information in order to facilitate communication among graduate students.

# Interdisciplinary Graduate Study and Research

In addition to offering graduate degrees within academic departments, Lehigh University offers interdisciplinary graduate degrees in the fields of applied mathematics, applied social research, clinical chemistry, management science, manufacturing systems engineering, molecular biology, molecular bioscience and biotechnology, physiological chemistry, and polymer science and engineering.

The university also affords opportunities for interdisciplinary study in areas of research. Programs in solid-state studies and municipal administration are examples.

In addition, Lehigh's 29 interdisciplinary research centers and institutes address the research needs of government, industry, and society. Organized to recognize research efforts in interdisciplinary problem areas, they supplement the university's academic departments. Graduate students pursuing M.S. and Ph.D. degrees in academic departments as well as students enrolled in interdisciplinary degree programs may pursue research opportunities in the various centers.

A complete listing of research centers, institutes, and other research organizations appears following the section on interdisciplinary graduate programs.

**Financial assistance.** Teaching assistantships and fellowships are provided by individual academic departments, while research assistantships are available through both academic departments and research centers. Students interested in research are encouraged to seek appointments with members of the faculty working in their area of special interest, with department chairpersons, or with center or institute directors.

## Interdisciplinary Graduate Programs

Several interdisciplinary programs are offered to the Lehigh graduate student.

### *Applied Mathematics*

Lehigh University offers interdisciplinary programs leading to the degrees of Master of Science and Doctor of Philosophy in Applied Mathematics.

Students may participate in the program either through the Division of Engineering Mathematics within the Department of Mechanical Engineering and Mechanics or through the Division of Applied Mathematics and Statistics within the Department of Mathematics.

The Ph.D. program is aimed at students with a background in mathematics, the sciences, or engineering who wish to obtain a thorough training and to develop their research ability in applied mathematics. Students will be admitted to one of the two divisions according to background and interests.

Seminar series in engineering science and applied mathematics in which visitors, faculty and students discuss current research, are available.

**Admission Procedure.** Applications are invited from students with backgrounds in engineering, mathematics or the sciences.

A complete application should include undergraduate and graduate transcripts, the aptitude part of the GRE, and at least two letters of recommendation. Foreign students must submit evidence of proficiency in English.

All applications are reviewed by the Department of Mathematics and Department of Mechanical Engineering and Mechanics. Students whose area of specialization is Applied Mathematics must register in one of the two departments and specify on their application the department of their choice. For application forms and information, write:

Prof. Philip A. Blythe, Head
Division of Engineering Mathematics
Packard Laboratory #19
Lehigh University
Bethlehem, PA 18015 Tel. (215) 758-3782

Prof. Gregory T. McAllister, Head
Division of Applied Mathematics & Statistics
Christmas-Saucon Hall #14
Lehigh University
Bethlehem, PA 18015 Tel. (215) 758-3730

Lehigh University
Alumni Memorial Building 27
Chairman of Coordinating Committee
Applied Mathematics Program
Bethlehem, PA 18015-9988

**Financial Aid.** Teaching assistantships are offered by both departments, and university fellowships and scholarships are offered by the Graduate School. Research assistantships are sponsored by governmental agencies and industry.

**M.S. Program.** A master's program must include at least thirty semester hours of courses.

Students in the Mathematics Department must pass a comprehensive examination in advanced calculus and linear algebra. They may replace up to six hours of course work with a thesis.

Research credits are obtained by registering in MATH 490—Mathematics Thesis.

Students registered in the ME/Mechanics Department must submit a thesis, which may replace up to six hours of course work. No comprehensive examination is required. Research credits are obtained by registering in EMA 490—Engineering Mathematics Thesis.

**Ph.D. Program.** The master's degree is not a requirement for the Ph.D.

A candidate entering at the bachelor's level must satisfy only the course requirements of the master's degree in the division in which he/she is enrolled. The candidate's advisor will recommend courses that help in preparing for the qualifying exams. Any additional course requirements will be determined by the student's dissertation committee. Students registered in the ME/MECH department obtain research credits by registering in EMA 499—Engineering Mathematics Dissertation.

Students registered in the Mathematics Department must satisfy the foreign language requirement. They may obtain research credits by registering in MATH 499—Mathematics Dissertation.

It is recommended that the qualifying examination be taken at the beginning of the fourth semester for students entering at the bachelor's level and at the beginning of the second semester for students entering with a master's degree.

The examination consists of three written tests. One is in analytical methods, one is on numerical methods or discrete mathematics, and one is on a topic from the physical or mathematical sciences as approved by the candidate's division.

## *Applied Social Research*

The applied social research program leads to the Ph.D. degree. The objective is to train specialists to consult on and to conduct applied social science research involving individuals, groups and social settings in business and industry, educational organizations, medical and human services programs, and governmental planning and policy making agencies. The interdisciplinary program is sponsored by the departments of psychology, social relations, and government in the College of Arts and Science, by the College of Business and Economics, by the College of Education and by the Center for Social Research. The training program includes relevant research techniques and strategies from the disciplines these departments and colleges represent.

In recent decades specialized methods have been developed for conducting research involving economic projections, market research, environmental and social impact analyses, experimental research, and program evaluation and to gather data for governmental and private planning and policy analyses. The methods have common features such as research planning, design and implementation, measurement design, sampling procedures, statistical analyses, computer applications and data management, interpretation and evaluation of results, and decision making based on the results.

The aim of the applied social research program is to develop methodological generalists who are knowledgeable in and have experience with the rather wide variety of methods required to conduct research in business, educational, social service, governmental and planning organizations. In contrast to academic settings where the tendency is to become increasingly specialized, the need in applied settings is for expertise in solving problems requiring a variety of social science research skills. In addition to a broad methodological background, the program provides the student with experience in conceptualizing, designing, implementing, interpreting, and communicating applied research.

**Program requirements.** Entrance requirements are a master's degree in social science, psychology, education or business, or in a field deemed by the coordinating committee to provide relevant background and sufficient quantitative skills to give some assurance of success in the program. A program of study and research will include courses in statistics, research design, measurement design, computer methods and research applications. A qualifying examination is given after 18-20 credits of work. Advanced courses, a research internship and a dissertation complete the requirements. Specifics of a student's program are to be worked out with a faculty adviser and depend on the student's past experience, educational and occupational goals.

**Financial aid.** Research assistantships, teaching assistantships, and fellowships or scholarships are available.

**Application for admission.** Requests for further information and for applications for admission should be directed to: Roy C. Herrenkohl, chairman, Applied Social Research Ph.D. Program Coordinating Committee, Center for Social Research, Lehigh University, 10 W. Fourth St., Bethlehem, Pa. 18015.

## *Clinical Chemistry*

The M.S. program in clinical chemistry is offered by the department of chemistry in cooperation with local hospitals. It is directed toward training clinical laboratory scientists to be active in hospital-based and industrial laboratories in both patient sample service and new product development. The program requires fulfillment of a clinical laboratory practicum as well as a research project at the M.S. level. The core requirements for the degree are:

| | |
|---|---|
| Chem 371 | Elements of Biochemistry I (3) |
| Chem 372 | Elements of Biochemistry (3) |
| Chem 332 | Analytical Chemistry (3) |
| Chem 336 | Clinical Chemistry (3) |
| Chem 358 | Advanced Organic Chemistry (3) |
| Chem 437 | Pathophysiological Chemistry (3) |
| Chem 439 | Clinical Laboratory Practicum (1 or 6) |
| Chem 421 | Chemistry Research (1-4) |

Electives or courses that may be substituted, upon an approved petition, for core requirements in clinical chemistry can be drawn from those listed in the Ph.D. programs in molecular biology or physiological chemistry (see below).

Students may be admitted into this program from undergraduate majors in chemistry, biology, medical technology, or other areas of the biochemical life sciences. One semester of undergraduate physical chemistry is required for the M.S. in clinical chemistry although in some cases this course may be taken while enrolled as a graduate student but for no graduate credit. Graduates of the program are encouraged to continue their education toward the doctorate in any one of the several biological chemistry programs offered at Lehigh.

## *Management Science*

The industrial engineering department, in conjunction with the department of management and marketing, offers an interdisciplinary degree in management science.

The management science program is directed toward integrating the scientific method with the functional aspects of organizations by investigating the application of quantitative methodology and systems analysis in the context of such functional areas as accounting, finance, marketing and production. This integration provides the student with a broader perspective toward managerial decision making in private enterprise and public administration.

Undergraduates with a background in engineering, business, economics, mathematics, or the physical sciences who want a professional career as a staff specialist in management science are appropriate candidates. In addition, those candidates who intend to seek line manager positions find the management science background advantageous in dealing with the complex problems of industrial, commercial, and public service organizations.

The candidate is assumed to have acquired basic competence in the areas of accounting, marketing, corporate finance, production, data processing, microeconomics, linear algebra, calculus, statistics, and introductory operations research.

**Required courses**

| | |
|---|---|
| IE 418 | Simulation |
| Mgt 321, IE 334 | Organizational Behavior |
| or Mgt 413 | and Structure |
| Eco 421 | Managerial Economics |
| IE (Mgt) 430 | Management Science Project |

nine hours of quantitative methods

six hours selected from a functional area

The minimum program consists of thirty hours of approved course work.

**Sample program**

| | |
|---|---|
| IE 418 | Simulation |
| Mgt 413 | Organization Behavior |
| IE (Mgt) 430 | Management Science Program |
| Eco 421 | Managerial Economics |
| IE 311 | Decision Processes |
| IE 417 | Mathematical Programming |
| Eco 455 | Econometric Models |
| IE 325 | Production Control |
| Fin 430 | Financial Management |
| Fin 431 | Advanced Investment Analysis and Portfolio Management |

## *Manufacturing Systems Engineering*

Lehigh's interdisciplinary graduate program leading to the master of science degree in manufacturing systems engineering (MSE) is sponsored by all the engineering departments in the College of Engineering and Applied Science. In addition, the College of Business and Economics participates in teaching management and other business aspects of manufacturing systems.

The graduate curriculum in MSE is designed to develop engineers who can design, install, operate, and change manufacturing systems that involve people, machines, new materials, information systems, and appropriate technology. The program integrates systems perspectives with interdisciplinary education and training.

**Program requirements.** The M.S. program in manufacturing systems engineering may be completed as a one-year, full-time program beginning each January.It requires a minimum of 30 credit hours of graduate study. The program is structured as follows:

**Spring semester**

Required courses:

| | |
|---|---|
| MSE 421 | Managing the Corporate Manufacturing Function (3) |
| MSE 423 | Product Design/Analysis (3) |
| MSE 425 | Production Planning and Resource Allocation (3) |
| MSE 427 | Production Systems (3) |

**Professional seminars:** Two-hour weekly seminars involving MSE topics, literature, case studies, and plant trips.

**Included summer project work (ten weeks):** One-week manufacturing management simulation game designed to teach the importance of information, integration, and cooperation across the traditional organizational lines of a manufacturing enterprise.

**Project or thesis option:**

**MSE 451. Manufacturing Systems Engineering Project (3)** Eight-week project work involving the solution of a problem in manufacturing systems engineering. A written report is required.

**MSE 490. Manufacturing Systems Engineering Thesis (6)** Students will conduct MSE thesis research beginning in the summer. Students will continue their thesis research in the fall semester.

**Additional summer project work:** One-week study tour visiting selected U.S. manufacturing plants, design centers, and research facilities. Students and faculty will analyze the use of modern MSE-related technology in each of the visited facilities.

**Fall semester:**

| | |
|---|---|
| MSE 431 | Management, Technology and Business Enterprise (3) |
| MSE433 | Technology and the Factory of the Future (3) |

**Professional seminars:** Two-hour weekly seminars involving MSE topics, literature, case studies, and plant trips.

**Elective courses** (6 or 9 credit hours): Students are required to take three approved elective courses with the exception of those students continuing their thesis work, who would take only two.

MSE-approved elective courses may be chosen from seven technical and business areas related to manufacturing systems engineering:
—Computer Aided Engineering (CAE)
—Automation and Computer Integrated Manufacturing (CIM)
—Manufacturing Information and Control Systems
—Manufacturing and Work Systems
—Business and Management Aspects of Manufacturing
—Design and Operation of Chemical Processes
—Modern Materials Technology
In addition to the regular classroom work, this program includes extensive use of Lehigh's CAD, CIM, AI, and robotics and manufacturing technology laboratories, as well as a variety of educational features to foster informal learning.

**Admission**
—A bachelor's degree in engineering or in another appropriate science is required.
—Candidates enroll in the MSE program through one of the university's engineering departments depending on their individual MSE specialization and interests.
—All candidates must follow the admission procedures and standards established by Lehigh University's Graduate School.
—Students enrolling in this program will be both industrial returnees and students with a B.S. degree going straight through college.

Qualified students completing their undergraduate degree requirements by May or June may apply to participate in the work-study internship program described below. Students graduating in December may apply to enroll in the MSE program immediately thereafter.

**Industrial internships.*** A special work-study internship program has been established as an option for qualified applicants desiring industrial experience before beginning the MSE program in January. A number of these industrial internships are available.

This intern program permits an applicant graduating with a B.S. degree in May or June to work with a participating company in an engineering or related science capacity for six to seven months before entering the MSE program.

**Financial aid.*** A number of graduate fellowships are available for qualified MSE applicants on a competitive basis.

**Special Activities Fee.** In addition to the applicable Lehigh University tuition, the MSE Program requires a special activities fee of $2,200 for 1988. Tuition and fees are expected to increase on a yearly basis.

**Inquiries.** For a brochure describing the MSE program, an application for admission (which includes an application for financial aid), or any additional information, please contact: Keith M. Gardiner, acting director, MSE Program, H.S. Mohler Laboratory 200, Lehigh University, Bethlehem, Pa. 18015. (215) 758-4667.
* Some industrial-internship and financial-aid restrictions may apply to foreign applicants.

## *Molecular Biology*

Graduate study in molecular biology is available within the department of biology as a program leading to the M.S. and Ph.D. degrees in molecular biology.

Students enrolled in the department of biology are provided with research space in the laboratories of the University's Center for Molecular Bioscience and Biotechnology on the Mountaintop Campus.

**Master's degree requirements.** The requirements for the M.S.

degree include thirty credits of graduate coursework, eighteen of which are at the 400 level, and successful completion of a research project. A thesis reporting the results of the research must be approved.

**Required courses**

| | |
|---|---|
| Chem 371 | Elements of Biochemistry I (3) |
| Chem 372 | Elements of Biochemistry II (3) |
| Biol 345 | Molecular Genetics (3) |
| Biol 461 | Molecular Cell Biology I (3) |
| Biol 462 | Molecular Cell Biology II (3) |
| Chem 479 | Biochemical Techniques (3) |
| or | |
| Biol 463 | Biomolecular Lab Techniques (3) |

Research (6)
Approved Electives (6)

**Ph.D. requirements.** Course requirements for the Ph.D. in Molecular Biology are determined on an individual basis by the student and the dissertation committee.

Near the time of completing the requirements for the M.S. degree, a student who wishes to pursue a Ph.D. takes a qualifying examination, which may be both oral and written. Upon successful completion of this examination (it may be taken no more than twice), the student, in consultation with the research advisor, selects a dissertation committee.

The centerpiece of the doctoral program is a concentrated research effort that culminates in a significant contribution to the field of molecular biology. Sometime prior to seven months before finishing the dissertation, the student must pass a general examination administered by the dissertation committee. The nature of this examination is determined by the dissertation committee.

The defense of the dissertation serves as the final examination for the doctorate. It is expected that the results of the dissertation research will be published in primary journals in molecular cell biology and/or biochemistry.

For further information, contact Jeffrey A. Sands, director, Molecular Biology Program, Room D230, Mountaintop Campus 111, Lehigh University, Bethlehem, PA 18015.

## *Molecular Bioscience and Biotechnology*

A new interdisciplinary graduate program leading to the degree of Master of Science in Molecular Bioscience and Biotechnology was initiated in 1987. The program is designed to serve as a broad based introduction to advanced study and research in biotechnology and the fundamental bioscience and bioengineering that is the foundation of modern biotechnology. Students are enrolled in the departments of biology, chemistry, or chemical engineering and take a set of core courses in molecular cell biology, biochemistry, and biotechnology and bioengineering and carry out a research project under the direction of faculty members of Lehigh University's Center for Molecular Bioscience and Biotechnology on the Mountaintop Campus. Students who decide to continue beyond the M.S. degree can enter from this program into Ph.D. programs in Molecular Biology, Biochemistry, or Chemical Engineering.

**Master's degree requirements.** The requirements for the M.S. degree include thirty credits of graduate course work, eighteen of which are at the 400 level, and successful completion of a research project. A written report of the research must be approved by the student's advisor and the program director.

**Required Courses for M.S.**

| | |
|---|---|
| Chem 371 | Elements of Biochemistry I (3) |
| Chem 372 | Elements of Biochemistry II (3) |
| ChE 341 | Biotechnology I (3) |
| ChE 342 | Biotechnology II(3) |
| Biol 461 | Molecular Cell Biology I (3) |
| Biol 462 | Molecular Cell Biology II (3) |

400-level approved laboratory course (3)
400-level approved advanced seminar (3)
Biol 407, Chem 421, or ChE 480 Research (6)

For further information, contact Janice A. Phillips, director, or Jeffrey A. Sands, co-director, Molecular Bioscience and Biotechnology Graduate Program, Mountaintop Campus 111, Lehigh University, Bethlehem, PA 18015.

## *Physiological Chemistry*

The graduate program in physiological chemistry leads to the M.S. and Ph.D. degrees. This curriculum prepares individuals who want to pursue careers in biomedical research, teaching, or administration, or in some aspect of public health.

Individuals may elect to specialize in one of the following areas: nuclear medicine, medicinal chemistry, chemical and experimental parasitology, invertebrate pathobiology, comparative immunology, and chemical physiology. The core course distribution and selection of electives may be altered to reflect the area of specialization.

**Core Courses**

Students select at least six of the following core courses:

| | |
|---|---|
| Chem 303 | Nuclear and Radiochemistry (3) |
| Chem 336 | Clinical Chemistry (3) |
| Chem 371 | Elements of Biochemistry I (3) |
| Chem 423 | Bio-organic Chemistry (3) |
| Chem 424 | Medicinal and Pharmaceutical Chemistry (3) |
| Chem 479 | Biochemical Techniques (3) |
| Chem 435 | Advanced Topics in Clinical Chemistry (3) |
| Chem 437 | Pathophysiological Chemistry (3) |
| Chem 477 | Topics in Biochemistry (1-3) |
| Biol 367 | Molecular and Cellular Biophysics (3) |
| | or any course in statistics |

Students, with the consent of their graduate committee members, may petition to substitute equivalent courses for some of the required ones. The substitution must be approved for the student's area of research concentration. In addition, each student selects, with the guidance of the committee, sufficient courses from the following to satisfy the requirements of the Graduate School.

| | |
|---|---|
| Chem 358 | Advanced Organic Chemistry (3) |
| Chem 372 | Elements of Biochemistry (3) |
| Chem 421 | Chemistry Research (1-4) |
| Chem 423 | Bio-organic Chemistry (3) |
| Chem 424 | Medicinal and Pharmaceutical Chemistry (3) |
| Chem 441 | Chemical Kinetics (3) |
| Chem 445 | Elements of Physical Chemistry (4) |
| Chem 458 | Topics in Organic Chemistry (3) |
| Chem 476 | Microbial Biochemistry (3) |
| Chem 480 | Advanced Biochemical Preparations (1-3) |
| Chem 481 | Chemistry Seminar (1-6) |
| Biol 133 | Invertebrate Zoology (3) |
| Biol 461 | Molecular Cell Biology (3) |
| Biol 353 | Virology (3) |
| Biol 402 | Comparative Animal Physiology (3) |
| Biol 405 | Special Topics in Biology (microbiology) (3) |
| Biol 415 | Cytochemistry (3) |
| Biol 464 | Ultrastructure Laboratory Techniques (3) |
| Hist 339 | Topics in American Public Health (3) |
| Hist 340 | Topics in American Medicine (3) |

Students admitted into this program may have majored in biology, chemistry, animal science, entomology, veterinary science, pharmacy, or some other areas of the life sciences.

All students in the doctor of philosophy program are required to satisfy one foreign language requirement and pass a qualifying examination. The completion of a research project is required of M.S. students. A dissertation is required of Ph.D. candidates.

For further information, contact Ned D. Heindel, Chandler-Ullmann 17, Lehigh University, Bethlehem, Pa. 18015.

## *Polymer Science and Engineering*

Lehigh has a diverse group of faculty members with strong, primary

interest in polymer science and engineering. In order to provide better opportunities for courses and research in this interdisciplinary field, activities are coordinated through the center for polymer science and engineering (CPSE), and its academic polymer education committee. Polymer faculty from traditional departments of chemical engineering, chemistry, and materials science and engineering, physics, and mechanical engineering and mechanics, are participants of the CPSE.

There are two ways in which qualified graduate students, with degrees in the above or related fields, may participate. They may pursue graduate studies within an appropriate department. Departmental procedures must be followed for the degree sought. The student's advisor may be in that department, or in another department, or research center. In this case, the student receives a normal departmental degree, with emphasis in polymer courses and research.

Alternatively, students may elect to pursue studies toward an interdisciplinary degree in polymer science and engineering. The procedures for this latter case are summarized as follows.

**M.S. in polymer science and engineering.** For the M.S., the student's program must include: not less than thirty credits of graduate work; not less than eighteen credits of 400 level course work, and not less than eighteen credits of course work in the major, of which fifteen must be at the 400 level. The program must include six course credits in the student's admitting department, six research credits, and complete a research report or thesis to the satisfaction of the faculty advisor, to be filed with the polymer education committee.

**Required courses:**

| | |
|---|---|
| ChE (Chem) 388 | Synthesis and Characterization Lab (3) |
| ChE (Chem) 393; Mat 343 | Physical Polymer Science (3) |
| ChE (Chem) 394 | Organic Polymer Science (3) |
| ChE (Chem) 483 | Emulsion Polymers (3) |
| ChE (Chem, Mat) 485 | Polymer Blends and Composites (3) |
| | Research (6) |

At least one additional 400 level polymer-related course. This may include other advanced polymer courses, electron microscopy (Mat. 334), colloid and surface chemistry (Chem 395), rheology (ChE 428), fatigue in polymers (Mat 418), or catalysis, (ChE 413), polymer processing (ChE 486), and/or other material related to polymer science and engineering. Courses in the admitting department must include one of the following:

| | |
|---|---|
| ChE (Chem) 400 | Chemical Engineering Thermodynamics (3) |
| Chem (ChE) 445 | Elements of Physical Chemistry (4) |
| Mat 410 | Physical Chemistry of Metals (3) |

plus either ChE 415, Chem 358. Chem 453, or Chem 458, or Mat 408.

**Ph.D. in polymer science and engineering.** For the Ph.D., the student must satisfactorily complete a qualifying examination administered by the polymer education committee, satisfactorily complete graduate course work determined in consultation with the doctoral committee, pass a general examination administered by the polymer education committee, and defend to the satisfaction of the doctoral committee, a dissertation in the field of polymer science and engineering. Students deficient in polymer science or related topics may be required by their committee to take remedial course work.

The doctoral committee consists of the research adviser, at least two members of the center for polymer science and engineering, and at least one outside person. The committee's composition is subject to approval by the polymer education committee and the graduate committee of the university.

For more information, write to Dr. M.S. El-Aasser, director, Center for Polymer Science and Engineering, Building A, Mountaintop Campus, Lehigh University, Bethlehem, PA 18015, or Dr. L.H. Sperling, chairman, Polymer Education Committee, Whitaker Laboratory 5, Lehigh University, Bethlehem, PA 18015.

# Research Centers and Institutes

Lehigh has developed a number of centers and institutes to provide greater research and academic opportunities for primarily graduate students and faculty. Centers and institutes are generally interdisciplinary and complement the scholarly activities of academic departments and represent scholarship and research based on the expertise and capabilities of a group of faculty members. Frequently, centers relate to the broad-based research needs of government, industry, and the social community.

## BioProcessing Institute

The BioProcessing Institute involves the education and research activity in the bioprocessing area of the Chemical Engineering Department at Lehigh University. The main focus of the research of this institute is on the processing problems related to the manufacture of products of interest to the biotechnology industries.

**Research interests.** The research thrusts of the institute include: fundamentals kinetics of microbial, mammalian and plant cell and enzyme systems; design and scale-up of bioreactor and bioseparation systems; modeling and control of bioreactor and bioseparation systems; development of instrumentation for the on-line monitoring of biological unit operations; and development of novel separation and purification schemes for recovery of biologically active macromolecules, antigens, and antibodies.

Specific examples of projects recently carried out within the institute are: development of scanning laser fluorometry and Fourier transform infrared spectroscopy for the on-line monitoring of substrate, product and cell concentrations; analysis of diffusional limitations and medium formulation for gel-entrapped mammalian cell systems; design of reaction systems for secondary metabolite production by plant cells; fundamental studies of separation systems such as continuous chromatography, aqueous two-phase extration, and electromolecular propulsion; kinetics of enzyme production by cellulolytic fungi/actinomycetes; kinetics of protein degradation and optimization of whey hydrolyzate as a substrate for the lactic acid fermentation; and plasmid stability in recombinant Saccharomyces cerevisiae.

The research is conducted in Building A, Mountaintop Campus where the laboratories for the Molecular Biology and Biochemistry research groups, the Department of Chemical Engineering, the Emulsion Polymers Institute, and the Chemical Process Modeling and Control Center are also located. Because of the interdisciplinary nature of the research, projects typically involve joint supervision by faculty from Chemical Engineering, Biology/Molecular Biology, and Chemistry/Biochemistry.

The BioProcessing Institute presently occupies 9000 square feet of laboratory space in the C wing of Building A of the Mountaintop Campus. The institute is equipped with an array of pilot-scale, computer-controlled bioreactors. Three computer systems are available for monitoring and control of these units: an IBM-XT, a DEC PDP 11/73, and a Leeds & Northrup MAX 1 Distributed Digital Control Unit. In addition, numerous small-scale reactors are available for batch and continuous culture work. Key emerging monitoring systems used on the pilot-scale fermentation equipment include a UTI Quadropole Mass Spectrometer, two BioChem Technology Fluromeasure Systems, and a Digilab/Bio-Rad FTS 60 FTIR Spectrophotometer. In addition, numerous small-scale bioreactors are available for batch and continuous culture work. Separations capability is being developed and currently includes a Romicon Hollow Fiber Unit, a Millipore Pellicon Unit, and a microprocessor-controlled Dorr-Oliver filtration unit.

The fermentation and separations facilities are supported by analytical equipment and facilities including UV/visible spectrometers, isocratic and gradient HPLC's with refractive index and variable wavelength UV/visible detectors, gas chromatographs with FID and TCD detectors, YSI glucose analyzer, Branson cell sonifier, incubator/shakers, laminar flow hood, microscopes, etc.

Mammalian cell cultivation is conducted in a recently constructed

class 1000 laboratory equipped with CO2 incubators, vertical laminar flow hoods, a Bellco roller bottle apparatus, Millipore Miili-Q purification system, inverted microscope, etc. A separate and similar facility exists for plant cell cultivation where a collection of drug producing plant species is maintained.

**Educational opportunities.** As listed in the course descriptions for the Department of Chemical Engineering, the faculty of the BioProcessing Institute conduct a variety of courses as part of the graduate education curriculum in biochemical engineering. The typical graduate level biochemical engineering curriculum would also include core courses in chemical engineering and basic science courses in microbiology, biochemistry and molecular genetics offered through the departments of biology and chemistry.

For more information, write to Janice A. Phillips, Director, BioProcessing Institute, Lehigh University, 111 Research Drive, Bethlehem, PA 18015.

## Center for the Application of Mathematics

The Center for the Application of Mathematics was established in 1965 to foster interdisciplinary research related to the application of mathematics, to draw on other disciplines for pertinent mathematical problems, and to encourage the development of advanced courses in the application of mathematics. There are currently research programs in the area of nonlinear continuum mechanics, the propagation of waves in nonlinear media, the study of thermally driven flows, variational calculus, numerical analysis, biomechanics, and the application of group-theoretic methods.

For more information, write to the center's director, Gerald F. Smith, Packard Laboratory 19, Lehigh University, Bethlehem, Pa. 18015.

## Center for Design and Manufacturing Innovation

The Center for Design and Manufacturing Innovation (CDMI) was established in April, 1984. The center had its origin in Lehigh's CAD/CAM program, a nationally recognized educational program started in 1979 that emphasized computer-aided design and computer-aided manufacturing. Since then the scope of the center has increased beyond CAD/CAM to include other areas of design and manufacturing, such as manufacturing technology, process systems engineering, computer-aided construction engineering, robotics, artificial intelligence, and microprocessor applications. CDMI functions both in an educational mode and also undertakes research and development within its principal activities.

The objectives of the center are based upon the premise that 'manufacturing' involves the whole production cycle from concept to the delivery of customer satisfaction. Thus design and manufacturing are inseparable activities which must be integrated with materials, processes, equipment, facilities, logistics and people. The Center's objectives are: (1) to make Lehigh University a national center of excellence for the study of manufacturing systems and design; (2) to stimulate research in the various areas of design and manufacturing; (3) to foster technology transfer with participating industrial organizations; (4) to promote the effective use of computers in engineering education; (5) to enhance laboratory development in appropriate areas related to design and manufacturing; (6) to coordinate campus-wide activities related to the use of computers in manufacturing systems; (7) to provide mechanisms to encourage professional development of faculty and also student growth; (8) to support the goals and objectives of the Ben Franklin Technology program; and (9) to provide the on-campus focus for the Ben Franklin program efforts in CAD/CAM.

**Computer-Aided Design Laboratory (CAD Lab).** This laboratory in the department of mechanical engineering and mechanics, is devoted to mechanical design, analysis and manufacturing. Five MicroVax IIs and a Vax 8350 support over 30 graphics devices with color and animation capability. An Ethernet-TCP/IP backbone also connect two HP Turbo-SRX workstations and a Vax GPX workstation. An integrated range of software supports wire-frame, surfaced wire-frame and solids models. Kinematic, dynamic and finite element analysis packages are also available. Manufacturing modeling software and associated departmental equipment support NC machining, sheet metal fabrications, thermoforming and plastic injection molding.

**Computer-Aided Engineering Laboratory (CAE Lab).** This laboratory in the civil engineering department includes a Data General MV 10000 computer to support approximately one dozen graphics workstations. Additional devices include ten standard alphanumeric CRTs, three hardcopy units, and a plotter. A variety of software supports computer-aided problem-solving in civil engineering. The CAE laboratory also serves to complement the experimental testing and research facilities of Fritz Engineering Laboratory.

**Design and Computing Systems Laboratory.** This laboratory in computer science and electrical engineering includes an Applicon 860 CAD interactive computer graphics VLSI Design Center and a Harris 800 computer system. The lab provides opportunities to study novel device-circuit structures that use advanced microelectronics technology and require computer-aided circuit design and computer-assisted characterization and modeling of electronic devices.

**Computer-integrated Manufacturing Laboratory (CIM Lab).** This industrial engineering department laboratory is equipped with a DEC PDP 11/34 for process monitoring and control and a variety of CAD/CAM systems, including an Applicon 4275 system (with VAX 11/750), and two IBM 4341 processors. More than two dozen graphics and alphanumeric terminals are located in this laboratory for student use. Available software includes solid modeling, VLSI design graphics, NC part programming, and simulation of factory scheduling, robotics, and automated manufacturing systems.

**Manufacturing Technology Laboratory.** This laboratory contains conventional and computer numerical control machine tools for research and instruction in turning, milling, drilling, and grinding operations. Instrumentation includes devices to measure cutting forces, surface finish, tool wear, and related process variables. Recent enhancements to the laboratory have emphasized material handling and automation. New equipment includes an automated guided vehicle system (AGVS), an automated storage and retrieval system (AS/RS), a cart-on-track conveyor system, a robotic assembly cell, and several programmable logic controllers and microcomputers for control and data collection.

**Compound Semiconductor Technology Laboratory.** This laboratory in the computer science and electrical engineering department was recently formed to help improve the U.S. competitiveness in semiconductor manufacturing technology. A clean room facility is being equipped for semiconductor growth and characterization, as well as metal deposition and photolithography patterning. Current research activities emphasize process modeling with the objectives to correlate material properties and in-process test parameters with the final device yield and performance.

**Intelligent Systems Laboratory (ISL Lab)** This CDMI/CSEE laboratory is equipped with a wide variety of computer workstations (IBM, SUN, Textronics), applications and applications development software, and computer networking facilities. The ISL facilitates research, development and instructional efforts in new and fundamental information systems concepts required to support next generation manufacturing systems. Specifically, ISL activities include manufacturing simulation, networking and communication, database design and management, control systems, production planning and control, production scheduling, group technology, and theoretical systems modeling and analysis.

**Industrial Engineering Information Systems Laboratory** The information systems laboratory of the industrial engineering department occupies approximately 1200 square feet on the 4th floor of Mohler Lab (room 453 and 453A). At the present time, this space is configured primarily as a classroom. Since much of the instruction in I.S. is at the undergraduate level, the department will continue to rely on L.U.C.C. to provide the bulk of the computing support for this activity. Graduate studies and research activities in I.S. within I.E. presents another picture. To the extent that our work is on the leading edge of technology, the I.S. Lab must seek to provide support which is qualitatively very different from that provided generally by L.U.C.C., and without unnecessarily duplicating facilities which might be made available either through the CIM Lab or the Intelligent Systems Lab. We have, however, led the way towards the introduction of UNIX, and this is being considered as the primary computing environment across the campus.

The present major thrusts within I.S. in I.E. are in the areas of artificial intelligence applications to manufacturing problems, and the application of object-oriented design and programming to modeling and simulation/emulation of manufacturing systems for investigation of problems both of design and scheduling/control. These thrusts imply the need for up-to-date powerful, graphics workstations to be made available both for instructional and research support.

**Microprocessor Applications Laboratory.** This industrial engineering department laboratory contains a variety of microprocessors, microcomputers, data acquisition systems, and programmable controllers. The purpose of this instructional and research laboratory is to study the problems of interfacing microprocessors and computers to industrial processes for monitoring and control.

**Robotics Laboratory.** This laboratory consists of an industrial applications division and a teaching division. The basic objective of the Robotics Laboratory is to serve the educational and research needs of the Institute for Robotics. The Robotics Laboratory is closely affiliated with several other laboratories at Lehigh, including the Computer Integrated Manufacturing (CIM) Laboratory, the Artificial Intelligence Laboratory, and the Manufacturing Technology Laboratory. Current activities within the laboratory include assembly, machine loading and unloading, welding, robot language design, machine vision, computer simulation including computer graphics simulation, control systems, kinematic and dynamic analysis, sensor systems, and control structures for flexible manufacturing systems.

**Educational programs.** The educational program most closely affiliated with the Center for Design and Manufacturing Innovation is the manufacturing systems engineering (MSE) program. The MSE program is a graduate interdisciplinary educational program designed to provide instruction and laboratory experience for engineers who will be planning, installing, and managing production systems in industry. The core curriculum consists of courses in production systems, product design/analysis, production planning and resource allocation, the corporate manufacturing function, technology management, and the factory of the future. Elective courses include a wide variety of subjects in design, automation and production systems, materials, chemical process engineering, information systems, and business.

In addition to the MSE program, other related programs are available in the regular academic departments in the College of Engineering and Applied sciences.

For more information, write to: Keith M. Gardiner, Acting Director, Center for Design and Manufacturing Innovation, Lehigh University, H.S. Mohler Laboratory #200, Bethlehem, Pa. 18015.

## Center for Economic Education

The Center for Economic Education was established in 1976. It is part of a nationwide network of more than 150 such centers under the guidance of the Joint Council for Economic Education.

For more than a quarter of a century, the Joint Council has been involved in programs to reduce the level of economic illiteracy in the United States. The purpose of Lehigh's center is to increase the quantity and improve the quality of economic education.

Located in Johnson Hall, the center is part of the College of Business and Economics. But it takes on an interdepartmental role as it coordinates programs aimed at heightening understanding of the American business and economic system. The center serves as a clearing house for educational ideas. It also houses an expanding resource library including books, films, filmstrips, curriculum material, testing packets, and stimulation games for use by faculty and area educators.

**Educational opportunities.** The center sponsors workshops, seminars and guest lectures designed to meet the educational needs of faculty and students. Sessions such as the American Iron and Steel Industry Economic Seminar allow members of the Lehigh community to meet with academic and business leaders to discuss economic issues relating to the industrial process.

For more information, write to the center's director, Warren A. Pillsbury, Center for Economic Education, Drown Hall 35, Lehigh University, Bethlehem, Pa. 18015.

## Center for Innovation Management Studies

The Center for Innovation Management Studies (CIMS) was established in 1984, in response to the needs of industrial executives and government officials for a university-based center to study the management of research and development and technological innovation.

The center's research program is interdisciplinary and involves research associates from several other universities. The center supports studies of the industrial innovation process, encourages publication in the professional literature, and trains students and business executives for technology management responsibilities through regular course offerings and continuing education programs.

The goal of this research is to enhance the contribution of technology to corporate performance and national productivity through an improved understanding of the technological innovation process and its management.

Under the direction of Alden S. Bean, Kenan Professor of management and technology and former director of the division of policy research and analysis at the National Science Foundation, the center is sponsored by 16 corporations, the Ben Franklin Partnership program, and NSF.

For more information, write to Alden S. Bean, director, Center for Innovation Management Studies, Johnson Hall 36, Lehigh University, Bethlehem, Pa. 18015, or call (215) 758-3427.

## Center for International Studies

Formed in 1986, the Center for International Studies develops, supports, administers and coordinates internationally oriented programs and activities throughout the University.

The center was established to strengthen the international dimension of Lehigh University by opening new opportunities for students to study and work abroad; by developing new interdisciplinary graduate programs; and by stimulating and supporting research in international affairs. The center offers programs in East Asian Studies, Canadian Studies and Russian Studies. In cooperation with the department of international relations, the center organizes the annual Cohen International Lecture Series which was made possible by an endowment established by Bertha and Bernard Cohen ('36). The center also sponsors seminars and guest lectures on international topics.

The center is run by an executive committee representing all four colleges. For more information, write to Z. J. Slouka, director, Center for International Studies, Lehigh University, 215 Maginnes Hall #9, Bethlehem, Pa. 18015. (215) 758-4745. For information on study abroad opportunities, contact Karen Keim, Study Abroad Coordinator, 216 Maginnes Hall #9, Bethlehem, PA 18015. (215) 758-3351.

## Center for Molecular Bioscience and Biotechnology

The Center for Molecular Bioscience and Biotechnology was established in 1986 by uniting faculty from the departments of chemical engineering, biology, chemistry, and civil engineering. Its mandates are to encourage interdisciplinary research directed toward understanding, characterizing, and harnessing microorganisms, viruses, plant and animal cells, and enzyme catalysts; to maintain well-equipped state-of-the-art laboratories; to promote intellectual camaraderie and cooperative research among center members.

The center is one of the best-equipped basic and applied biotechnology facilities in the country. In addition to the laboratories of individual members (mainly biochemical and microbiological), the center has a central pilot plant facility in Homer Laboratories comprising approximately 4,000 square feet. It is well equipped with a variety of bioreactors including batch and continuous bench-top fermentors ranging from 300 cc to 30 liters; pilot-scale fermentation

equipment ranging in size from 28 to 250 liters, and pilot-scale membrane filtration units along with associated computer control and monitoring systems.

The financial mainstay of the center is standard contract research from government funding agencies and private companies. In addition, the Biotechnology Liaison Program encourages private companies to maintain strong ties with the university by supporting, through a single program, proprietary research and nonproprietary fundamental research of general interest. Through the program, member companies gain access to university resources, stay in touch with the current basic research in academe and have the opportunity to influence the direction and emphasis of this work. Center faculty associates and their students benefit by keeping aware of the latest developments and needs of the private sector and by being provided with new research ideas and opportunities.

**Research activities.** Center research activities include: basic microbiology and virology including strain selection and development; basic fermentation studies dealing with kinetics, transport phenomena, modeling, automatic control, optimization, and fermentor design; scale up of fermentation process; biological treatment of municipal and industrial wastes; recovery and purification of fermentation products; economic studies.

Current research projects include: enzyme immunoassay conjugate synthesis; cell fusion as a method of viral attenuation; yeast enzymes in ethanol biosynthesis; microbial desulfurization of coal; fermentation broth rheology; computer control and monitoring of fermentations; oxygen transfer rate, and mixing time characteristics of the fermentors; use of fluorometry and IR spectroscopy for monitoring and controlling biological processes; development of cellulolytic bacteria and fungi; and optimization of cellulase production in batch culture.

**Educational opportunities.** The center welcomes graduate and undergraduate students from any academic department to do degree or nondegree-related research under the direction of faculty associated with the center. Center activities and facilities are diverse and flexible enough to meet the needs of any student interested in various aspects of biotechnology ranging from basic microbiology and biochemistry to engineering design. Regardless of a student's specific goals, he or she will be immersed in a rich and stimulating environment where there is a high level of intellectual camaraderie and cooperative activity through which each participant can obtain an appreciation of the general area of biotechnology.

Graduate students doing dissertation research in the center receive degrees from existing academic departments. (The center does not grant degrees.) Generally, the student's adviser will be a center faculty associate, although he or she may not be from the student's own department. This affords the student great flexibility in choosing a research area. Also, the close associations in the center make it easy for the student to obtain guidance from several faculty experts.

Courses dealing with all areas of biotechnology are offered through the departments of chemical engineering, biology, chemistry, and civil engineering. Most are taught by the center's faculty associates who work together to integrate existing courses and to formulate new ones as the need arises. Also, the broad range of expertise allows for team-teaching of appropriate courses.

The center sponsors an active seminar schedule that includes prominent speakers from around the world. It also emphasizes presentations made by faculty and students associated with the center. Seminar topics range from basic microbiology and biochemistry to the design and economics of fermentation plants.

Continuing education is another important activity of the center. This component includes, but is not limited to, short courses of various degrees of specificity as well as practical training programs dealing with subjects ranging from basic laboratory skills to the operation of large, computer-coupled fermentors.

For more information about the center's activities and financial assistance for graduate students, write to Arthur E. Humphrey, director, Center for Molecular Bioscience and Biotechnology, 111 Research Drive, Lehigh University, Bethlehem, Pa. 18015.

# Center for Polymer Science and Engineering

The Center for Polymer Science and Engineering (CPSE) was formally established at Lehigh University in July 1988. The Center provides a unique opportunity for faculty and students from the traditional departments of chemistry, chemical engineering, materials science and engineering, mechanical engineering and mechanics, and physics to perform interdisciplinary research in polymers. The Center is an umbrella organization encompassing polymers research and graduate studies at Lehigh University. The Center's primary missions are preparation of first rate scientists and engineers with proficiency in polymers; fostering cross-disciplinary polymer research; and organizing and teaching continuing education short courses in areas of interest to the polymer industry; and organizing campus wide seminars.

The Center's Polymer Education Committee graduate studies through the academic departments leading to the Master of Science and Doctor of Philosophy in Polymer Science and Engineering. Students may also elect to pursue studies towards a classical degree in their respective departments with an emphasis in polymer courses and research. Both advanced undergraduate and graduate courses in polymer science and engineering are offered through the participating departments. Current course offerings include polymer synthesis and characterization, physical polymer science and organic polymer science, engineering behavior of polymers, rheology, polymer processing, emulsion polymers, biopolymers, polymer blends and composites, fatigue and fracture of engineering materials, and colloid science.

**Research activities.** The center has a wide range of research activities covering the field of polymers. The following are the major research themes: Surface/interfacial aspects of polymer colloids, adhesion, and polymer blends and composites; polymerization mechanisms and kinetics; polymerization reactors modeling and control; structure/properties relationship of interpenetrating polymer networks; macromolecular chemistry of biopolymers and coal; polymer coatings for corrosion protection, mircoelectronic packaging.

**Research facilities.** The following research instrumentation are available for the center for polymer science and engineering: X-Ray Photoelectric Spectroscopy (ESCA), Scanning Auger Electron Spectroscopy, Laser Ramon Spectroscopy, Mossbauer Spectroscopy, Nuclear Magnetic Resonance Spectroscopy of both solids and solutions (NMR) (3 instruments; 90 MHz, 300 MHz and 500 MHz), Fourier Transform Infrared Spectroscopy (FTIR) (both conventional and photo-acoustic), a variety of advanced transmission and scanning electron microscopes, several calorimetry devices, instruments for rheological studies (including a Weissenberg Rheogoniometer and Bohlin Rheometer), particle sizing instruments (Coulter N4M, Joyce-Loebl Disc Centrifuge, Capillary Hydrodynamic Fractionation, and Hydrodynamic Chromatrography), Gel Permeation and Gas Chromatography units, Electrophoretic Mobility apparatus, mechanical testing devices such as the Rheovibron Dynamic Mechanical Spectroscopy, Instron Tensile Test equipment, several computer-controlled servohydraulic fatigue test machines, and Polymerization Reactors, including Bottle Polymerizer, Tubular Reactor, Stirred Tank Reactors with on-line sample analysis for residual monomer and interfaced with computer for control operations.

**Educational opportunities.** Programs of study for individual students are designed to meet the student's interests, the requirements of the academic department, and the student's dissertation committee. Considerable flexibility is permitted in the selection of courses and a research topic. Lehigh University has been awarding interdisciplinary M.S. and Ph.D. degrees in Polymer Science and Engineering since 1975. Graduate students conducting polymer research may also earn the M.S. and Ph.D. degrees in the classical fields of chemistry, chemical engineering, materials science and engineering, physics, or mechanical engineering and mechanics. For further information please refer to the Polymer Science and Engineering Program in the section: Interdisciplinary Graduate Programs.

For more information about the center activities, admission to graduate school, or financial aid, contact; Dr. Mohamed S. El-Aasser, Director; Center for Polymer Science and Engineering,

111 Research Drive, Room D330, Lehigh University, Bethlehem, PA 18015; (215) 758-3590.

## Center for Social Research

The Center for Social Research is a multidisciplinary organization designed to stimulate and conduct research involving the social and behavioral sciences.

Several disciplines are involved in the activities of the center: economics, political science, psychology, sociology, anthropology, marketing, and international relations. The center also cooperates with the university's other research centers and with several science and engineering departments.

Founded in 1965 as the Center for Business and Economics, the focus of the center was later broadened, and the name changed to the Center for Business, Economics and Urban Studies. The center's early activities included research on economics and business forecasting, and on transportation problems. The change to include urban studies broadened the center's scope to encompass the disciplines of political science, sociology, and history. In 1972, the center's scope was further broadened to include behavioral science and international affairs, and the present name was selected to more accurately reflect this broadened focus.

**Interdisciplinary research.** The social perspective of the center's research is interdisciplinary in nature and is relevant to the community outside the university—local, regional, national, and international. Many research activities are based on a cooperative university-community relationship through which the research goals of the center are achieved and community needs met. Interdisciplinary research activities of the center are currently being conducted in the following areas:

**Health and Human Development.** Members of the departments of psychology, economics, social relations, government, education, environmental biology, and chemistry participate in research on health and human development. The program focuses on life from early childhood to maturity. Research interests include the effect of prenatal loss on families and family members; the influence of family and community on health; management aspects of organizations that serve elderly individuals; public and private pension systems; psychological aspects of aging; design of housing for the elderly, and health and education in later life.

Recently completed projects have examined relationships between apportionment of service agency budgets and agency managerial objectives, inclusion of elderly persons in college courses, reactions of long-term residents to neighborhood change, and a study of cognitive functioning in the later years.

**Families and Children.** Members of the departments of government, psychology, social relations, and economics participate in studies pertaining to families and children. Research interests include family dynamics and child rearing practices and the emphasis on families included under the health and human development program, particularly the influence of community organization and dynamics on the health of residents. Current research focuses on the effect of child rearing practices on children's development of competence.

**Program evaluation.** Members of the departments of social relations, economics, and accounting participate in research to evaluate the effects of a variety of programs. Particular emphasis is on improving program evaluation methodology. Current research interests include evaluation of several business, science and engineering programs in the university. Research has recently been conducted on the effect of compensatory education programs.

**Urban technology.** The urban technology program includes faculty from several university departments. The primary focus of the program is to provide an integrated, interdisciplinary approach to current urban problems. The program serves as a visible liaison point for both city officials and university researchers. Recently completed research includes energy conservation and cost-reducing methods for local government, storm water management, computer mapping, information systems, vehicle maintenance scheduling, municipal productivity, and program budgeting. Many of these activities began as a part of the Allentown, Pa., Urban Observatory, originally funded by the U.S. Department of Housing and Urban Development through the National League of Cities. The projects are now carried on by the city of Allentown.

**Educational opportunities.** Master's and doctoral-level degrees are offered through the departments with which CSR cooperates. An interdisciplinary doctoral program in applied social research is offered jointly by the departments of psychology, government and social relations in the College of Arts and Science, by the College of Business and Economics, by the College of Education, and by the Center for Social Research. This program emphasizes training in research methodology relevant in nonacademic settings (see description under Interdisciplinary Graduate Programs).

For more information, write to Roy C. Herrenkohl, director, Center for Social Research, 203 East Packer Ave., Lehigh University, Bethlehem, Pa.18015.

## Chemical Process Modeling and Control Research Center

The Chemical Process Modeling and Control Research Center (PMC) is a university-industry cooperative research center performing innovative generic and applied research that addresses the chemical processing industry's needs. Founded in 1985, the center is funded by the National Science Foundation and through the membership fees of a consortium of industrial companies.

Sixteen faculty members collaborate in the research and teaching responsibilities of the center. They bring expertise from academic disciplines such as chemical, mechanical, industrial and electrical engineering, and diverse research areas such as polymer reaction engineering and biotechnology.

Prior to the establishment of the center, Lehigh faculty members, in collaboration with industrial representatives, assessed the research needs in the area of process modeling and control. This assessment recognized that rapid technological advances are driving engineering toward cross disciplinary interactions. It identified several trends that have already affected and will continue to affect the chemical, petroleum, petrochemical and biochemical industries in the next decade. These trends have generated the need for an intensified research effort in chemical process modeling and control. They define the research mission of the center.

Membership fees support generic research that focuses on advanced, practical methods and tools that are pertinent to several processing problems. Examples of problems of interest to the center are: effective multivariable process control techniques; distillation control; expert control; batch reactor control; reactor modeling; process simulation, and plant-wide control. Member companies often propose new research problems for the consideration of the center's faculty. Their suggestions help define the generic research activities of the center and ensure that the center's research is aimed at solving a class of significant industrial problems.

**Research Activities.** More than ten generic research projects have been initiated as active projects. These projects, representing major research challenges, are as follows: nonlinear control structures for chemical reactors; design of practical multivariable process controllers; design and control of energy-efficient distillation column systems; modeling and control of bioreactors; monitoring and control of emulsion copolymerization; plant-wide control; expert multivariable control; batch reactor control; statistical quality control; diagnostic identification.

Some of the other research and educational activities of the center include week-long short courses in a wide range of areas; progress reports of the research activities that are released to member companies twice a year; an exchange program in which industrial researchers come to Lehigh University to participate in the research program; and the development of specific contractual research arrangements between member or nonmember firms and center faculty members.

**Educational opportunities.** Due to its special character and mission, the PMC Research Center offers unique educational

opportunities to students who wish to receive a graduate degree with research specialization in the area of process modeling and control. In recognition of the growing need for an engineering education that cuts across the engineering subdisciplines, the center actively involves faculty and students with varied backgrounds and expertise. Furthermore, with its research and educational activities, the center aims at lessening one of the primary weaknesses in present-day engineering education, namely, the understanding of how engineering knowledge is converted by industry into social goods and services. This goal is served by the center's generic and, by its applied research activities and by a comprehensive series of graduate and undergraduate courses, invited industrial and academic speakers, and group meetings and seminars.

All Lehigh University control courses are coordinated and cross listed between the departments of chemical, mechanical, and electrical engineering. Group meetings and seminars are used as a mechanism for the increased transfer of information and ideas among center graduate students and industrial researchers from the member firms. Distinguished academic and industrial researchers, in the areas of process modeling and control, are invited to Lehigh for extended series of lectures and in-depth discussions of current research topics.

To make undergraduate students more aware of the challenges and rewards of research, the center offers them opportunities to participate with graduate students in research. This provides graduate students with an opportunity to be a researcher and a teacher/supervisor at the same time.

For additional information about the center, contact Christos Georgakis, director, Center for Chemical Process Modeling and Control, 111 Research Drive, Lehigh University, Bethlehem, Pa. 18015-4791, (215) 758-4781.

## Emulsion Polymers Institute

The Emulsion Polymers Institute, established in 1975, provides a focus for graduate education and research in polymer colloids. Formation of the institute constituted formal recognition of an activity that had grown steadily since the late 1960s.

The institute has close ties with polymer and surface scientists in the Center for Polymer Science and Engineering, Zettlemoyer Center for Surface Studies and the Materials Research Center, Center for Chemical Process Modeling and Control, and the departments of chemical engineering and chemistry.

Polymer colloids or polymer latexes, as they are more commonly called, are finely divided polymer particles that are usually dispersed in an aqueous medium. Important products produced and utilized in latex form include synthetic rubber, latex paint, adhesives and paper coatings. The small particle size of typical latexes make their colloid properties as important as the polymer properties for a number of applications. Hence, the study of emulsion polymersis an interdisciplinary activity.

**Research activities.** Emulsion polymers research includes a broad range of problems in the areas of preparation, modification, characterization, and application of polymer latexes. Most commercial polymer latexes contain a number of important ingredients; some in only small quantities.

Research programs at Lehigh are aimed at understanding the function of recipe components during preparation and application of the latexes. The research projects are a blend of fundamental and applied efforts as well as a mixture of theoretical and experimental problems: emulsion polymerization kinetics, mechanism and morphology of core/shell latexes, colloidal surface and bulk properties of polymer colloids, dispersion polymerization, mechanism and kinetics of inverse emulsion polymerization, miniemulsions, alkali-swelling behavior of carboxylated latexes, inverse suspension polymerization, NMR studies of polymer colloids, electrophoresis of polymer colloids, coating by electrodeposition, and associative thickeners.

Significant research support for institute activities is obtained from industrial organizations through their membership in the Emulsion Polymers Liaison Program. Hence some considerable effort is made to relate the research results to industrial needs. Consequently, graduates can find excellent opportunities for employment.

**Educational opportunities.** Graduate students in the institute undertake dissertation research leading to the master of science or doctor of philosophy degrees in existing science and engineering curricula or in the polymer science and engineering program.

Programs of study for individual students are designed to meet the student's interests, the requirements of the appropriate academic department, and the student's dissertation committee. Considerable flexibility is permitted in the selection of courses and a research topic.

Faculty members of the institute are involved in teaching normal university courses and continuing education courses for industrial personnel. The annual one-week short course, Advances in Emulsion Polymerization and Latex Technology, typically attracts about 100 industrial participants and 20 Lehigh students. This course is an important mechanism for developing meaningful interactions between institute staff and students and industrial scientists and engineers. Educational and research opportunities exist for postdoctoral students and visiting scientists as well as resident graduate students.

For more information, write to John W. Vanderhoff or Mohamed S. El-Aasser, 111 Research Drive, Lehigh University, Bethlehem, Pa. 18015.

## Energy Research Center

Energy research at Lehigh is a multidisciplinary activity, involving faculty and students from engineering, the physical sciences, life sciences, business and economics, and the social sciences. The Energy Research Center provides a structure within which faculty and students from different backgrounds can explore their specific research interests.

The center coordinates the university's energy research, helping the faculty respond to research opportunities and developments in energy. It is also the major contact between the university and industry and government for matters dealing with energy research. Originally founded in 1972 as the Task Force for Energy Research, the center was organized into its present form in 1978.

The research within the center involves a wide range of topics related to the supply and use of energy. Work in progress—supported by contracts and grants from government, industry, and private foundations—deals with fuels and energy resources, energy conversion systems, energy conservation and the environment.

The Energy Research Center has particularly close ties with industry. A number of joint research projects involve Lehigh faculty and students and research staff from industry. The center also operates the Energy Liaison Program, through which participating companies and government facilities have access to faculty consultants, make use of laboratory facilities and library services, and receive assistance on research problems, feasibility studies and other projects related to energy. Through the center's Energy Intern Program, opportunities also exist for students to receive part of their training in industry. Through this program, a graduate student involved in energy can do a research internship in industry under the joint supervision of company research staff and the student's faculty adviser.

Experimental support for energy research is provided in a number of specialized laboratories maintained by the university. These laboratories, furnished with the latest instrumentation and equipment, include the following: boiling and two-phase flow, fluidized bed, fluid mechanics, surface chemistry, chemical kinetics, GC/mass spectrometer, atomic absorption spectrometer, electron optical, mechanical testing, structural testing, welding, metal forming, fracture mechanics, ceramics, polymer, hydraulics and water resources, van de Graaff accelerator, biotechnology, aquatic biology, and microprocessor development.

All faculty members who participate in Energy Research Center activities belong to academic departments. In addition, a number of faculty and staff members affiliated with the center have close ties with other on-campus research centers and institutes, assuring broad interactions between center personnel and experts from many research specialties, including economics, social science, materials and metallurgy, marine biology, fracture and solid mechanics, metal forming, structural design, sanitary and water resources engineering, thermal science, fluid mechanics, surface chemistry, and biotechnology.

**Energy research.** Research within the center falls within five major categories. Projects of interest include:

**Fossil fuels.** Fluidized bed combustion of coal; heat transfer in

fluidized beds; pulverized coal combustion; catalytic combustion; cyclonic combustion; coal slagging; freezing of coal; coal chemistry; microbial desulfurization of coal; kinetics of coal gasification; fluidized bed gasification; dynamic simulation of coal conversion systems; kinetics of coal liquefaction; hydrogen-enhanced crack growth in high-strength steels; organic coatings for flue gas desulfurization service; weld repair of steam turbine rotors; mechanical properties of cryogenic steels for LNG applications; toughness of pipeline steels; fracture analysis of pipelines; mechanisms of tertiary oil recovery.

**Nuclear technology.** Instrumentation for reactor safety studies; boiling heat transfer in water-cooled reactors; fracture toughness of reactor steels; static and dynamic fracture toughness of steel welds; microstructural characterization of pressure vessel welds; pressure vessel design, radioactive waste disposal; high-energy particle physics, nuclear physics.

**Environmental impact of energy systems.** Oil pollution studies in the coastal and wetlands environment; effects of power plant operations on biological life in the New Jersey estuarine region; acid rain; trace metal contamination of aquatic ecosystems; hazardous waste disposal and control.

**Conservation and renewable resources.** Biological conversion of cellulose to chemicals and fuels; catalysis for alcohols from biomass; energy recovery from municipal solid waste; fuel derived from waste water treatment; energy conservation in the metal-forming industries; instrumentation and analysis of industrial processes; use of computers for process control; development of microprocessors for residential load control; cooling of electric utility generators and high-capacity electric motors; design of cryogenic turbines; instrumentation for HVAC applications; siting of wind-power applications.

**Energy economics.** Dynamic analysis of energy supply-demand systems; model of an investor-owned electrical utility; peak-load pricing of electricity and natural gas.

**Educational Opportunities.** The extensive involvement of faculty in energy research has created a wide range of opportunities for graduate studies in energy. Most of the departments in the College of Engineering and Applied Sciences, as well as several departments within the College of Arts and Science and the College of Business and Economics, are active in energy research and offer both masters and doctoral degree programs suitable for studies of energy-related topics.

All degrees are granted by the academic departments and graduate students interested in energy enroll in traditional graduate degree programs in departments of their choice. These students specialize in energy by complementing their programs with a selection of special energy-related courses. They pursue their graduate research in energy areas under the supervision of faculty from the Energy Research Center or from other research centers or academic departments.

Opportunities also exist for students to receive part of their training in industry through a program in which a graduate student involved in energy can do a research internship in industry under the joint supervision of company research staff and the student's faculty adviser. The Energy Intern Program is individualized: each internship is designed to meet the specific needs and interests of the student, the faculty adviser and the company.

Financial support for graduate students is available through the Energy Research Center by means of fellowships and research assistantships related to sponsored research.

Each year Lehigh faculty members offer a number of special energy-related courses at the undergraduate and graduate levels; many of them are outgrowths of current faculty research. Recent examples include courses dealing with energy economics, the international politics of oil, nuclear reactor engineering, public policy and nuclear power, air pollution, coal catalysis, coal technology, materials for modern energy systems and solar energy.

The Energy Research Center also sponsors an annual seminar series, bringing some of the outstanding people in the energy fields to the campus to speak. Covering a range of topics from economics to energy policy to science and engineering, these seminars provide an opportunity for faculty and students to learn of new developments in energy.

For more information, write to Edward K. Levy, director, Energy Research Center, Packard Laboratory 19, Lehigh University, Bethlehem, Pa. 18015.

# Engineering Research Center For Advanced Technology For Large Structural Systems (ATLSS)

The ATLSS Engineering Research Center was established in May 1986 with a grant from the National Science Foundation (NSF) to assist structures-related industries. Currently, about 60 persons, including graduate students, research associates, faculty and staff members representing the various disciplines important to large structural systems are active in research at the Center.

The Center has three main research thrusts: Advances in Design Concepts, Innovation in Fabrication and Construction, and advances in In-Service Monitoring and Protection. Each thrust addresses the critical needs of a different section of the structures industry. A fourth thrust relates to the ATLSS Experimental Laboratories. The Center is cross-disciplinary, drawing from disciplines such as design, materials, manufacturing, robotics, computer-technology, chemistry and coatings technology, business and finance. Most of the ATLSS research studies are conducted in close association with advisory committees of engineers and scientists from industry, government, design and professional groups and other universities.

In addition to the excellent research facilities and equipment already available at Lehigh, including the structural testing facilities of the Fritz Engineering Laboratory, the ATLSS Research Center opened major new experimental facilities in early 1989. These new facilities include a world-class large-scale multidirectional loading facility in which researchers will evaluate large complex connections, assemblages and structures under static and/or cyclic loading. Computer-controlled testing at the new facility includes distributed control of tests; data acquisition, processing and display, and report production. The new facility also includes new CAE and welding laboratories.

**Research Activities:**

**Advances in Connection Technology**—an integrated effort to advance connection technology in steel, concrete and mixed construction and to establish a connection design methodology through cross-disciplinary research involving designers, fabricators, computer scientists, material scientists and metallurgists.

**Knowledge Base for Steel Structures**—an interim step for developing a national Technical Information Center for Steel Structures that will make available technical information from both published and unpublished reports so as to respond to requests for data directly related to specifications and design criteria.

**Development of Construction Automation Technology**—the application of automation, including robotics, to the construction environment for a variety of tasks, such as water-jet cutting, connection techniques and inspection.

**Knowledge-based Expert Systems** —the development of real-time decision support systems. Current examples include a designer-fabricator interface that will enable designers and fabricators to collaborate efficiently in evaluating design alternatives and making appropriate fabrication decisions for construction projects, and a portable knowledge-based expert system to guide an engineer through a bridge inspection, to shorten the inspection time, enhance the quality of the inspection, and assess fatigue and fracture damage.

**Diagnostic Sensors for Structures**—the development of new sensors as well as new applications for non-traditional sensors in monitoring structural performance. The studies have resulted in new sensors for corrosion monitoring, and studies are proceeding using acoustic emission, image monitors, and vibration monitors.

**Educational Opportunities:**

The ATLSS Center facilitates programs of study and research that cross the traditional boundaries of engineering curricula, providing a fundamental, broad approach to the field of structures.

Graduate students participating in the Center's program usually receive master of science, master of engineering, or doctor of philosophy degrees in the academic discipline of their choice, i.e.,

civil engineering, material science and engineering, computer science, industrial engineering, mechanical engineering, etc. However, they are expected to pursue course work related to a broader understanding of structures and to conduct research on a cross-disciplinary problem in the Center.

Financial support for graduate students is available through the ATLSS Research Center by means of fellowships and research assistantships related to sponsored research programs.

Undergraduates are also encouraged to participate in the Center's research and educational program. Opportunities for summer internships are available which will enable more intense and direct involvement in the Center's research effort.

For more information, write to the director, John W. Fisher, 117 ATLSS Drive, Lehigh University, Bethlehem, PA 18015.

## Environmental Studies Center

The Environmental Studies Center (ESC) is a multidisciplinary research organization with the primary purpose of fostering research opportunities in the broad fields of environmental science and engineering, coastal engineering, estuarine ecology, aquatic chemistry and biology, and environmental studies.

The center staff includes faculty and graduate students from the departments of biology, chemistry, civil engineering, geological sciences, mechanical engineering and mechanics, physics, chemical engineering, economics, social relations and urban studies.

Effective utilization of the resources of the environment and their protection requires the cooperation of many scientific and engineering disciplines. Practical solutions will most likely be achieved for the many critical environmental problems facing the world through a combination of engineering and scientific talent, coupled with economic and political decision making. An environmental scientist or engineer needs an unusually broad background in many disciplines, as environmental problems are invariably cross-disciplinary in nature, i.e., solid, hazardous wastes.

**Research activities.** A broad spectrum of research activities is included within the scope of the center. Although much of the research is done in facilities of various academic departments, ESC has laboratories in Williams Hall (environmental biology and marine sedimentology), in Chandler-Ullmann Hall (environmental engineering, estuarine ecology, environmental geotechnology), Fritz Laboratory (water and waste-water analysis and treatment), and an off-campus estuarine and marsh station near Stone Harbor, N.J. Lehigh University is a member of the New Jersey Marine Sciences Consortium and has access to its facilities, laboratories, and boats.

Current research activities reflect the interests of the present center staff, and include: physiologic response of marine invertebrates to sublethal pollutants; reproductive strategies of shipworms in coastal thermal effluents; coastal salt marsh food-chain relationships; marine vertebrate behavior studies; biochemistry of marine bacteria; near shore sedimentation; oceanic sedimentation on the continental slope and rise; beach sedimentation processes; control, management and treatment of toxic and hazardous wastes; waste soil interactions; effects of industrial and municipal pollution on surface and subsurface water resources; advanced wastewater treatment methods; improved control of treatment plants through automation; acid deposition effects; economics of resource development and environmental protection; and utility planning and management.

**Educational opportunities.** Graduate students may undertake thesis or dissertation research under the supervision of faculty associated with the center, who are members of an academic department; all courses are taught within academic departments. The program of courses to meet the student's special field of interest and to satisfy departmental and Graduate School requirements is determined by consultation with the academic department chairperson or a special departmental faculty committee.

Environmental engineering and coastal engineering courses are offered by the civil engineering department. Courses related to environmental studies and marine science are offered by the departments of biology, chemistry, chemical engineering, civil engineering, geological sciences, economics, and government.

For more information, write to the chairperson of the appropriate academic department, or to the center director, Irwin J. Kugelman, Chandler-Ullmann Hall 17, Lehigh University, Bethlehem, Pa. 18015.

## Fritz Engineering Laboratory

Founded in 1909, Fritz Engineering Laboratory is involved in the advancement of knowledge and techniques in the fields of structures, structural mechanics, materials, hydraulics and fluid mechanics and geotechnics.

The laboratory is associated primarily with the department of civil engineering. In addition, there are cooperative research efforts with other departments and with other institutes and universities. Research projects are sponsored by national research councils, through the university office of research, and by industry and governmental agencies.

Graduate studies combined with research investigations commenced at Fritz Engineering Laboratory in 1928. A major expansion of the facilities in 1955 was followed by addition of equipment to meet the needs of new research opportunities.

The staff consists of faculty members, research associates, research assistants, and supporting administrative, technical and clerical personnel. The laboratory awards research assistantships and certain fellowships to competent research personnel who are candidates for advanced degrees. Students from departments and divisions such as civil engineering, metallurgy, mechanical engineering and mechanics, and information science are able to take advantage of research opportunities with the laboratory.

Through their work in research programs, individuals are trained for careers in teaching, in research, and in advanced engineering design.

**Research activities.** The current research divisions indicate present interests and activities of the laboratory staff and include the following:

Fatigue and fracture (brittle failure due to cyclic and impact loading); geotechnical engineering (soil, foundation, rock and pavement mechanics); hydraulics (stream and channel flow, hydrology, sediment transport in pipes and channels, coastal engineering, groundwater movement); building systems (behavior and strength of building components, frames and over-all systems, problems involved in the design of high-rise buildings, earthquake and wind responses); structural concrete (prestressed and reinforced concrete bridges and buildings); structural connections (welded and bolted joints, composite structures); and structural stability (buckling of plates, beams, columns and frames); environmental engineering (hazardous waste control, water supply, solid-waste incineration).

The operations division provides services for laboratory work, and includes an instrumentation group and a computer systems group, the latter maintaining close liaison with the university's computing center.

As a result of the research studies conducted by the staff of the laboratory, it has been possible to make basic changes to design procedures and specifications in many specialty fields. The laboratory participates in a worldwide exchange of research information, maintains a library of technical papers appropriate to its fields, and stimulates the publication of papers in technical journals both in this country and abroad.

**Educational opportunities.** Through the laboratory organization, technical seminars and lectures are presented on current research findings and on new design applications in the various fields of civil engineering and related disciplines.

Courses students select are primarily in their own department. However, to gain a broader understanding, many students choose courses from the departments of biology, chemical engineering, chemistry, civil engineering, geological sciences, industrial engineering, mechanical engineering and mechanics, and metallurgy and materials engineering.

For more information, write to Irwin J. Kugelman, Fritz Engineering Laboratory 13, Lehigh University, Bethlehem, Pa. 18015.

## Health Sciences Institute

The Health Sciences Institute, organized in 1972, is concerned with interdisciplinary research and graduate and postdoctoral training in various aspects of the biomedical sciences and engineering.

The center is comprised of two divisions: the division of biological

chemistry and biophysics, and the division of bioengineering. Facilities are provided by these divisions for its members, postdoctoral fellows, and graduate students actively engaged in research in the respective areas.

A large part of the research conducted at the center is supported by private and public agencies and all are related to either basic or applied aspects of problems pertaining to human and animal life.

**Research activities.** The research opportunities and programs of each division are described below.

**Division of biological chemistry and biophysics.** Interests currently represented among the thirteen faculty members include the following: immunochemistry applied to clinical diagnostics, modification and use of monoclonal antibodies in radiosensitization and NMR imaging, surface adhesion in biological systems, glycoprotein structure and function, cell-cell interactive proteins, tumor image enhancement, medicinal chemistry, neuroendocrinology, motility and behavior of cells, chemistry of biologically potent molecules, manipulation of bacterial genetics, and recombinant DNA biotechnology.

The administrative offices of the division and most of the laboratories are housed in the Seeley G. Mudd Building. The laboratories are well equipped, and the major pieces of equipment include three NMRs, mass spectrometers, numerous liquid and gas chromatographs, tissue culture laboratory, bacterial transfer room, fermentors, warm room, cold rooms, scintillation and gamma counters, UV-Vis and infrared (including Fourier transform) spectrophotometers, ultracentrifuges and ancillary equipment necessary to conduct the above studies.

This division has an ongoing liaison programs with Hahnemann University and Lehigh Valley Hospital Center; clinical aspects of several research projects are being conducted there.

**Division of bioengineering.** This unit of the center is concerned with a number of health-related problems that are best resolved by individuals with a background in engineering. Ongoing projects include the study of transport phenomena in the microcirculation, especially capillary-tissue fluid exchange and oxygen transport to tissue; flow in flexible tubes and past constrictions, modeling the venous system and arteriosclerosis; mathematical modeling and experimental studies on the biomechanics of the foot; fracture mechanics of skeletal units, and shock propagation in the human body.

**Educational opportunities in the Health Sciences Institute.** Graduate students working under the direction of members of various components of the center may satisfy course requirements towards the M.S. and Ph.D. degrees by selecting from the offerings of the departments of chemistry, physics, biology, psychology, civil engineering, mechanical engineering and mechanics, as well as other departments.

In addition, the interdisciplinary graduate program in physiological chemistry leading to the master of science and the doctor of philosophy degrees is supported by the Health Sciences Institute, although all of the students are enrolled in the department of chemistry. Students may also pursue graduate degrees in biochemistry, organic, clinical chemistry, or molecular biology under supervision of center faculty members.

In addition to research, the center sponsors symposia as well as annual series of seminars on topics pertinent to its objectives.

For more information, write to the director, Jack A. Alhadeff, CMBB, 111 Research Drive, Lehigh University, Bethlehem, PA 18015.

## Iacocca Institute

The Iacocca Institute was established in 1987 with the support of Lee A. Iacocca, chairman of the board and chief executive officer of Chrysler Corporation, and a member of Lehigh's Class of 1945. Its mission is to develop research and education programs to study and enhance global competitiveness throughout American industry.

Building on Lehigh's leadership in developing innovative, productive education-business-government partnerships, the Institute provides a forum for cooperative exploration of ways to boost the nation's economics performance and industrial productivity.

An interdisciplinary resource, the Iacocca Institute is an integral part of Lehigh University. Its executive director reports to the vice president and provost, the University's chief academic officer. In addition to developing specific, focused programs, the institute serves as a catalyst for increased synergy and coordination among Lehigh's established centers of research and teaching. Also among the institute's key objectives is enhancing the leadership capabilities of current and future Lehigh students for a globally competitive environment.

A distinguished advisory board provides close ties with industry. Its members are Lee A. Iacocca, chairman and chief executive officer, Chrysler Corp. (chairman of the advisory board); Dexter F. Baker, chairman, president and chief executive officer, Air Products and Chemicals, Inc.; Douglas A. Fraser, former president, United Auto Workers, University Professor of labor studies, Wayne State University; William C. Hittinger, former executive vice president, research and engineering, RCA Corp.; Terry R. Lautenbach, senior vice president, International Business Machines Corp., and general manager, IBM-United States; Drew Lewis, chairman and chief executive officer, Union Pacific Corp.; Peter Likins, president, Lehigh University; David M. Roderick, chairman and chief executive officer, USX Corp.; Felix G. Rohatyn, senior partner, Lazard Freres & Co.; Walter F. Williams, chairman and chief executive officer, Bethlehem Steel Corp.

For more information, write to Laurence W. Hecht, Director, Iacocca Institute, 111 Research Drive, Lehigh University, Bethlehem, PA 18015.

## Institute for Biomedical Engineering and Mathematical Biology

The institute for Biomedical Engineering and Mathematical Biology was established July 1, 1988 to foster interdisciplinary research and support graduate study in the application of engineering and mathematics to medicine and biology. Faculty from several engineering departments and from mathematics and biology actively participate in the Institute. Current research includes the mathematical analysis of transport and exchange in microcirculatory physiology, theoretical and experimental biomechanics, experimental biofluidmechanics, fracture and failure in skeletal units and in prostheses, shock propagation through the human body, and design for the handicapped.

The Institute has established an extensive network of interaction and generated significant research collaboration with a number of major medical centers. An effective liaison program fosters interaction between the University and industry in the biomedical field.

Graduate students interested in studying biomedical engineering or mathematical biology at Lehigh enroll in one of the engineering departments or in the applied mathematics program, and satisfy the corresponding degree requirements. The Institute provides the opportunity for interdisciplinary research for both the master's thesis and the Ph.D. dissertation.

For further information, write to Eric P. Salathe, director, Institute for Biomedical Engineering and Mathematical Biology, Chandler-Ullmann Hall 19, Lehigh University, Bethlehem, PA 18015.

## Institute for Marine Studies

This Institute is designed to coordinate and enhance marine programs in biology, goelogy, coastal engineering, and anthropology. Here graduate students will be able to sample a diversity of marine fields and develop exciting interactive research programs.

The biological research programs involve both basic and applied programs in physiology, animal behavior, benthic ecology, and population genetics. The physiological aspects focus on the swimming energetics of crustaceans and the effects of petroleum pollution on metabolism. The behavioral research involves the territorial defense and habitat options of coral reef fishes and the interrelationships between shorebird predation on the life histories of shallow estuarine fishes. Ecological aspects include programs on the consequences of asexual reproduction, regeneration, and competitive interactions among invertebrate (both colonial and non-colonial) species. Programs in population genetics emphasize adaptive

processes and include the influence of migration and gene flow between populations inhabiting discontinuous habitats (e.g., islands, salt pannes, and estuaries). The anthropological research considers the social and biological dimensions of fisheries management as well as the regulatory policies. For the past twenty years the biological research has focused on the estuaries of southern New Jersey but more recently has expanded with opportunities available to graduate students in the Caribbean and the Pacific coast.

The coastal engineering programs emphasize both laboratory and field work, along with the development of numerical models. Recent field studies, conducted primarily on the New Jersey coast, emphasize tidal flow circulation, sediment deposition rates, erosion processes, shore protection and the stability of coastal structures, finite element and boundary element analyses of wave induced pressures on buried pipelines, and fluidization of channels. The geotechnical program is concerned with properties of soft saturated ocean-bottom sediments, low strain shear stress-strain behavior of soft saturated clays, large scale experimental modelling of lateral soil forces on offshore pipelines, and numerical modelling of sediment deformation under tectonic stresses and mudflows under cyclic loading. In conjunction with geologists and biologists, the civil engineering group is concerned with numerical hydrodynamic and sedimentation models for tidal lagoons.

Faculty in the Department of Geological Sciences are involved in marine sedimentology and geophysical studies. Research on sediment deformation associated with subduction is conducted off the Oregon/Washington coast and is currently directed to determining the hydrologic conditions under which deep sea sediments dewater under tectonic convergence. Inshore studies in New Jersey involve examination of sediment flux and hydraulic evolution in salt marshes. The geophysical program focuses on factors controlling the accuracy of paleomagnetic signals in marine sediments. These studies include inspection of the effects of compaction, tectonic strain, and depositional lineation induced by bottom currents.

**Stone Harbor Marine Laboratory.** The Institute is responsible for managing this marine laboratory at Stone Harbor, New Jersey. The laboratory has several boats for inshore work, a running sea water system used to maintain live specimens, and dry lab space. Beside the Stone Harbor Marine Laboratory, several faculty maintain close research ties with other marine laboratories in Jamaica, Belize, Oregon, and Washington.

**Educational opportunities.** Formal graduate studies are offered through the graduate programs with various departments of the university (e.g., biology, geological sciences, civil engineering). Research internships for advanced undergraduates desiring hands-on experience are also offered.

For additional information write to: Murray Itzkowitz, director, Institute of Marine Studies, Williams Hall 31, Lehigh University, Bethlehem, PA 18015, or Charles Wahle, director, Stone Harbor Marine Laboratory, 359 96th St., Stone Harbor, NJ 08247.

## Institute for Metal Forming

The Institute for Metal Forming, sponsored by the department of materials science and engineering, was established in 1970 to teach the principles and applications of metal-forming technology to graduate and undergraduate students; to provide instruction and equipment for graduate research in metal-forming processes; and to assist industry with solutions to problems in metal forming.

Metal-working processes are analyzed mathematically, usually involving the computer. The results of the analyses are checked and refined by comparison with experimental data obtained in the fully instrumented metal-forming laboratories that are part of the institute's facilities.

In addition, an important part of the effort of the institute is the preparation of educational programs using the latest audio-visual techniques in integrating expert systems provided as software for personal-computer users. These programs are used in the classroom and in institute-sponsored seminars on campus and at industrial facilities.

Long-range planning, together with major equipment acquisitions and construction, is supported by university funds, federal funds, and an industrial consortium.

**Research activities.** Current research areas include: hydrostatic estrusion; pressure-induced ductility; flow through converging conical dies; effect of holes, inclusions and pressure on tensile properties; friction modeling and measurement; cladding and forming of composite materials; forming of polymers; deep drawing, impact extrusion and iron rolling; and powder consolidation. Special emphasis is currently being given to fabrication of high-temperature ceramic, super-conducting wire, and to computer simulation of metal forming processes.

**Educational opportunities.** Students interested in metal forming should refer to course descriptions in Section V for metallurgy and materials engineering and mechanics. In addition, the institute offers special informal seminars and lectures for graduate students.

For more information, write to the director, Betzalel Avitzur, Whitaker Laboratory 5, Lehigh University, Bethlehem, Pa. 18015.

## Institute for Robotics

The Institute for Robotics was established in August, 1982, to foster interdisciplinary education and research related to industrial robotics and automated systems, to draw on the various disciplines for which pertinent automation-related problems exist, and to encourage and support the development of undergraduate and graduate courses in industrial robotics and automation and production systems. The creation of the Institute for Robotics is a formalization of the ongoing activity in industrial robotics at Lehigh since the late 1970s. More than twenty-three faculty members from five departments in the College of Engineering and the College of Arts and Science are performing research in robotics or in automation-related areas.

The institute serves a dual function of fostering educational programs and providing research facilities and opportunities at both the undergraduate and graduate levels. As a first step, the institute has established a robotics laboratory to be used as a teaching vehicle in support of courses. The laboratory is equipped with several teaching robots with micro-processor and computer control systems for experiments in industrial robotics. In addition to the teaching robot laboratory, the institute is establishing a major research facility with industrial-grade equipment. Equipment and software have been installed and are being gathered to set up manufacturing cells. This facility will also provide robotics research capabilities in areas including welding, assembly, flexible manufacturing systems, and the interface of robots with machine tools and material handling systems. A significant portion of the needed equipment has been gathered to date with the help of industrial and governmental grant and research projects.

**Research interests.** Members of the institute have research interests in a variety of areas including the following: robot programming languages, operating systems and simulation; the design and analysis of robot manipulators under static and dynamic conditions; distributed control architecture for robots and factory systems; control of sensors and the integration of sensors to robots systems; pattern recognition image processing and voice processing; the link between robots and CAD/CAM systems to use common data bases as well and to develop computer assisted robot programming using graphic techniques; simulation of robots and manufacturing cells; the interface between robots and other components of the factory floor, and the connection to factory control systems; and the design of special purpose and articulated hands for robot applications.

New courses have been developed and several undergraduate senior projects, master theses, and Ph.D. dissertations are underway. Students interested in the Institute for Robotics are encouraged to contact the institute directly for an up-to-date profile of institute courses, research opportunities, and activities.

For more information, write to Nicholas G. Odrey, director, Institute for Robotics, H.S. Mohler Laboratory 200, Bethlehem, Pa. 18015.

## Institute for the Study of the High-Rise Habitat

The Institute for the Study of the High-Rise Habitat was established in January, 1983, by the trustees of Lehigh University for research and instructional programs. It provides a focus for studies of both the technological and socioeconomic aspects of tall buildings, as well as

their role in the urban environment. The dissemination of new findings and the development of information are key elements in the program. The Fazlur Rahman Khan Chair, an endowed faculty position for research, instruction, and lecturing, is established within the context of the institute.

The Institute for the Study of the High-Rise Habitat demonstrates its concern not only with the high-rise buildings, but also with the entire scope of the urban environment and the cultural aspects of building technology. There is concern about the liveability of the structure, its suitability to the environment for which it is planned, and the urban planning and design problems that exist as a whole.

The institute, provides a center for study, research activities, information dissemination, and stimulation of the use of new information in design.

**A forum for faculty discussion.** The institute provides a forum for faculty discussion, not only from the different disciplines on the campus as they relate to the high-rise environment (architecture, history, business and economics, informational science), but also for visiting fellows and professors.

**Research.** The institute provides the opportunity to identify research problems and seek mechanisms for their solution, either in the traditional mode or in a workshop environment. This can include the traditional single-discipline research, interdepartmental projects and joint projects carried out with other universities.

**Special lectures and short courses.** The institute hosts special lectures and seminars for students and visitors on selected topics, to be given by faculty and other specialists in the field. The institute organizes short courses on campus or elsewhere. Special study programs can be arranged that include a lecture series at Lehigh followed by visits to selected cities for on-the-spot evaluation. These can be arranged for multi-professional teams of visiting specialists.

**Study opportunities.** In addition to special study programs for graduate and undergraduate students, the resources of the institute are available to visiting scholars.

For more information write to Tom F. Peters, Institute for the Study of the High-Rise Habitat Chandler Ullman 17, Lehigh University, Bethlehem, Pa. 18015.

# Institute of Fracture and Solid Mechanics

The Institute of Fracture and Solid Mechanics was established in the fall of 1970 to enable faculty members and students within the university to participate in research relevant to fracture and solid mechanics on an interdisciplinary basis. A branch of this Institute was establish in the Republic of China in 1987 to carry out cooperative research activities.

An area of special interest to the institute has been in fracture mechanics, which deals with the study of structural and material sensitivity to flaws. Such flaws can seriously affect the design and strength of ships, aircraft, automobiles, bridges and buildings. In the design of nuclear power plants, the incorporation of the fracture mechanics concept of safety in the presence of flaws is required. In addition, fracture mechanics is finding application in such areas as bone fracture, environmentally accelerated cracking of pavements and structural members, the fracture of rocks, and erosion of materials by solid or water particle impingement.

The institute centralizes many activities in the field of solid and fracture mechanics. These activities include: expansion of research capabilities to include the application of concepts of fracture mechanics to geology (rocks), medicine (bones), and composite materials; editing books on timely subjects in fracture and solid mechanics; compilation and collection of written materials to establish and maintain a special library of fracture mechanics; planning of conferences on fracture and solid mechanics; offering short courses and seminars on special topics; conducting liaison programs with industry and government agencies.

**Research activities** There are several research programs being conducted in solid and fracture mechanics, sponsored by industry and governmental agencies. They include:

**Fracture mechanics.** Analytical: stress analysis of engineering structures weakened by flaws; spherical and cylindrical shells with mechanical imperfections; crack extension in viscoelastic and rate sensitive materials; thermoelastic analysis of crack problems; heat generation at the crack tip region in metals; vibration and impact of solids containing cracks; three-dimensional analytical and finite element studies of surface and through cracks; fracture behavior of layered and fiber-reinforced composites; elastic-plastic solutions of crack problems.

Experimental: static and dynamic fracture roughness testing of metallic, nonmetallic and composite materials; crack-extension resistance curve measurements for aluminum and titanium alloys and steels; glass-to-rubbery transition temperature in viscoelastic materials; velocity measurements of running cracks; fatigue crack propagation in pressurized shells and shells under membrane load; combined loading (biaxial, tension-bending, etc.) of thin plates with cracks; photoelastic studies of stress distribution in cracked and composite bodies; environmental effects on crack propagation under static cyclic loads; fatigue crack propagation under programmed loading; gaseous hydrogen embrittlement.

**Solid mechanics.** Analytical and numerical methods of analysis: conformal mapping technique applied to potential solutions; two-and three-dimensional asymptotic expansions near geometric discontinuities; integral transform solutions leading to Fredholm integral equations; singular integral equations with generalized Cauchy kernels; application of the Chebyshev and Jacobi polynomials; methods based on the Gauss-Jacobi quadrature formulas; special applications of numerical treatment and finite elements to continuum problems involving singularities; convergence of finite element solutions for continuum mechanics problems.

Plates and shells; development of advanced plate and shell theories; load-deflection and instability behavior of elastic and plastic shells of revolutions; composite and sandwich shells subjected to static and dynamic loadings; dynamics of magnetoelastic shells.

**Educational Opportunities.** Students interested in fracture and solid mechanics should refer to course offerings in the departments of mechanical engineering and mechanics, metallurgy and materials engineering, civil engineering, chemistry and biology.

For information, write to the director, George C.M. Sih, Packard Laboratory 19, Lehigh University, Bethlehem, Pa. 18015.

# Institute of Thermo-Fluid Engineering and Science

The Institute of Thermo-Fluid Engineering and Science, established in 1978, provides a focus for research and educational activities in fluid mechanics, thermodynamics, and heat transfer.

This institute seeks to consolidate the substantial ongoing research effort in these fields, to aid in the further development of such research, and to facilitate the utilization of this interdisciplinary strength in the university's educational programs.

Currently twenty-two full-time faculty and staff from the departments of chemical engineering, mechanical engineering and mechanics, mathematics, and physics are among the institute members. Graduate students and undergraduates as well as part-time and visiting staff members, join in the institute's activities.

Research facilities for thermo-fluids programs are based in the College of Engineering and Physical Sciences. Among the facilities available are laboratories for experimental investigations of fluid mechanics, gas dynamics, turbulent structure, solid-gas fluidization, boiling heat transfer and two-phase flow, refrigeration and heat pump systems, internal combustion engines, radiation and optical measurements, unit operations, and control dynamics. The university's Computing Center as well as various minicomputers are available for use in analytical computations.

The institute also conducts the Thermo-Fluids Liaison Program, to promote the interchange of knowledge between the researchers at Lehigh and the engineers and scientists in industry and government. In cooperation with companies participating in the liaison program, the institute's staff members seek to apply their specialized capabilities in thermo-fluids to current industrial and governmental engineering and scientific problems.

**Research activities.** The institute's staff members are involved in three interrelated areas: fluid mechanics, heat transfer and thermal science, and applied thermodynamics and modeling.

Combining experimental investigations with theoretical analyses, the researchers seek to understand and quantify the phenomenological mechanisms governing thermo-fluid processes.

This knowledge is then brought to bear on relevant engineering problems of current concern in such applications as energy conservation, power production, coal conversion, aerodynamics, weather modeling, and nuclear energy.

The institute's current research program includes more than twenty grants sponsored by industry and various governmental organizations. A wide spectrum of subjects are under investigation, including research on flow-induced vibrations, unsteady turbulent flows, coherent turbulent boundary layer structures, blade flutter in compressors and fans, stochastic optimal control, colloid size distributions by hydrodynamic chromatography, fluidized combustion of coal, heat transfer in fluidized beds, heat pump systems, two-phase flow instrumentation, boiling heat transfer and two-phase flows, and nuclear reactor thermal safety.

**Educational opportunities.** Formal courses in fluid mechanics, heat transfer, and thermodynamics are offered in the College of Engineering and Physical Sciences. Institute staff members regularly teach both undergraduate and graduate courses in the departments of mechanical engineering and mechanics, chemical engineering, and physics. Undergraduates can select a program of study, in consultation with their adviser, with emphasis on thermo-fluid sciences by elective choices among the departmental offerings. A formal minor program in fluid mechanics is available. Graduate studies leading to the M.S. or Ph.D. with concentration in thermo-fluids are available in the three departments.

Participation by both undergraduate and graduate students in the thermo-fluids research activities is encouraged. Many undergraduates participate as individuals or as groups in term projects under the supervision of institute faculty members. This provides an opportunity for interested students to obtain first-hand experience in pioneering thermo-fluids research. The research programs directed by institute staff members also provide support for graduate research assistantships, enabling selected graduate students to pursue their education and research in thermo-fluids on either a part-time or full-time basis.

In cooperation with various academic departments, the institute sponsors seminars by both staff specialists and by invited speakers from other institutions. These seminars are open to the university community, liaison program participants, and to engineers and scientists from neighboring industries. The institute anticipates organizing topical meetings, workshops, and short courses on specialized subtopics within the over-all discipline. Meeting topics will be selected to reflect ongoing research activities of the staff members and contemporary engineering concerns.

For information regarding the Institute of Thermo-Fluid Engineering and Science, write to the director, John C. Chen, 111 Research Drive, Lehigh University, Bethlehem, Pa. 18015.

## Intelligent Systems Laboratory

The Intelligent Systems Laboratory was established in July, 1987, to foster interdisciplinary education and research related to integrated systems for manufacturing. The creation of this laboratory is a formalization of the ongoing research activity in modern manufacturing systems at Lehigh University.

**Research Interests:** The ISL is designed to provide a facility which permits the exploration of the new and fundamental information systems concepts required to cope with the next generation of manufacturing systems. Activities in or planned for the laboratory include: Simulation of the manufacturing environment; network and communication systems; distributed database design and management; information and control systems; production planning and control; scheduling systems methodology; group technology applications and systems development; constraint based analysis and theoretical modelling. It is important to point out that the ISL approach does not begin and end with technology. Strategic objectives, tactical management requirements, and the base technologies must be integrated and designed for feasible organizational acceptance and operation. The ISL is dedicated to pioneering and development, measurement and evaluation of these systems.

For more information, write to Roger N. Nagel, director, Intelligent Systems Laboratory, Mohler Lab 200, Lehigh University, Bethlehem, PA 18015.

## Lawrence Henry Gipson Institute for Eighteenth-Century Studies

The Lawrence Henry Gipson Institute for Eighteenth-Century Studies, established in 1971, serves as a memorial to one of America's most distinguished scholars, and long-time member of the faculty at Lehigh.

It helps to support the research activities of the Lehigh community of humanists and social scientists interested in developing a further understanding of the period of history epitomized in Professor Gipson's monumental life work, *The British Empire Before the American Revolution* (15 volumes, written from 1936 to 1970). The professor won the Pulitzer Prize for Volume 10.

Through its council, the Gipson Institute awards research grants and fellowships from the income of its endowment, a fund made possible by Professor Gipson's bequest of his entire estate to Lehigh. To further the scope of the original endowment, the council of the institute seeks additional support by promoting research and other programs related to the eighteenth century.

**Research activities.** The income from the endowment of the Gipson Institute, and other funds, provide faculty research grants to defray travel cost, microfilming, and other such expenses; graduate student grants to help support deserving students during their dissertation year; internal seminars to bring together the eighteenth-century interests of faculty and graduate students and to stimulate interdisciplinary research activities. These seminars are broad in scope and include faculty from neighboring institutions. Interdisciplinary graduate courses in eighteenth-century studies provide students, who normally concentrate on one discipline, with a grasp of other significant developments and an understanding of the rich cultural and intellectual milieu of the eighteenth century. Such courses stress the interrelationship of history, politics, literature, fine arts, philosophy, psychology, and the sciences.

Annual symposia honor Professor Gipson, involving distinguished scholars in eighteenth-century studies to lecture and also discuss opportunities for further scholarly exploration. The institute also provides additional research resources for the library, as well as faculty and student fellowships for the pursuit of research in an eighteenth-century topic.

**Educational opportunities.** Among the academic departments involved in eighteenth-century studies are English, government, history, modern foreign languages and literature, philosophy, psychology, and social relations.

For more information, write to the directors, James S. Saeger, department of history, or Jan Fergus, department of English, Maginnes Hall 9, Lehigh University, Bethlehem, Pa. 18015.

## Lehigh Valley Center for Jewish Studies

The Lehigh Valley Center for Jewish Studies, established in 1984, develops, administers, and coordinates programs in Jewish studies among member institutions of the Lehigh Valley Association of Independent Colleges (LVAIC) (Lehigh University, Muhlenberg College, Lafayette College, Moravian College, Cedar Crest College, and Allentown College of St. Francis de Sales). The center supports and encourages shared course offerings as well as the exchange of faculty among LVAIC institutions. Additional faculty in Jewish Studies, housed at Lafayette College, Lehigh and Muhlenberg College, are associated with the center. In addition to teaching on their home campuses, these faculty offer Jewish studies courses on other LVAIC campuses each semester. A visiting scholar from Isreal is in residence at the center annually and teaches courses at Lehigh and other LVAIC schools. Housed at Lehigh, the Center for Jewish Studies is directed by Laurence J. Silberstein, Philip and Muriel Berman professor of Jewish Studies.

Activities of the center include designing and implementing new courses and seminars, establishing research grants for undergraduate students, sponsoring study programs abroad for undergraduates, organizing annual lecture series, and sponsoring colloquia and conferences in Jewish studies at LVAIC institutions. The center coordinates year-long, semester and summer study programs in

Israel at the Hebrew University, Tel Aviv University, and the Tel Miqne-Ekron Archaeological Project. For further information on Israel study programs, contact Dr. Myra Rosenhaus, 758-3352.

Philip and Muriel Berman of Allentown, Pa., in consultation with Judaic scholars from the United States and Israel, conceived of and provided the initial funding for the center. Their goal was to establish in the Lehigh Valley a first-class academic program for the study of all aspects of Jewish civilization. The center customarily opens its programs to the public.

For more information about the Center for Jewish Studies, please contact Dr. Laurence J. Silberstein, 758-4869.

## Martindale Center for the Study of Private Enterprise

The Martindale Center for the Study of Private Enterprise was established in 1980 by a gift from Harry and Elizabeth Martindale. The primary purpose of the center is to contribute through scholarship to the advancement of public understanding of the structure and performance of our economic system.

Attention is focused on the private sector of the economy and on public policies as they influence the private sector. To achieve this end, the center activities include the sponsorship of lectures and conferences, support of faculty research and case studies, administration of the visiting scholar and executive-in-residence programs and the publication of two journals, PERSPECTIVES ON BUSINESS AND ECONOMICS, and the LEHIGH REVIEW OF BUSINESS AND ECONOMICS. The center sponsors and administers the Martindale Students Association Program (for undergraduates) and the Martindale-Rauch Scholars Program (for MBA students).

For more information, write to the center's director, J. Richard Aronson, Martindale Center for the Study of Private Enterprise, Drown Hall 35, Lehigh University, Bethlehem, PA 18015.

## Materials Research Center

The Materials Research Center was established in 1962. Currently, approximately 140 persons, including graduate students, research associates, and faculty members representing science and engineering departments, are engaged in research pertaining to materials science and engineering.

The fundamental objectives of the Materials Research Center are to encourage interaction among the science and engineering disciplines with an interest in materials and to promote interdisciplinary research activity and interdepartmental educational opportunities. To achieve these objectives, the center seeks to establish a climate in which faculty members, research scientists, postdoctoral associates, and graduate assistants develop an awareness of materials, arrange for facilities and space required to conduct interdisciplinary research; guide the search for new materials by encouraging fundamental research and new approaches to materials problems; and assist in developing educational opportunities in materials—in particular, interdisciplinary graduate programs devoted to training for research in materials.

The center also conducts the Materials Liaison Program. Founded in 1963, this program promotes the interchange of knowledge between the materials community at Lehigh and engineers and scientists in industry and government. The program conducts seminars on materials research, special lectures and workshops on items of current interest; consults on materials problems and research; distributes master of science and doctor of philosophy theses and abstracts of materials research; and sponsors seminars with outstanding invited speakers.

The staff consists of members of the departments of chemistry, chemical engineering, materials science and engineering, and physics. Members of other departments and centers frequently are involved in cooperative programs. Communication with these associated units is achieved through the Materials Research Council, which is composed of senior faculty members from all of the engineering departments as well as from the department of geological sciences and appropriate research centers. The council serves in an advisory capacity as well.

**Research Activities.** The present organization of the Materials Research Center includes four laboratories: the electron optical, ceramics, and polymer research laboratories, located in Whitaker Laboratory; and the mechanical behavior laboratory, located in Coxe Laboratory. Current interdisciplinary research activities include:

**Electron optics.** Characterization of fracture surfaces in polymers and steels by scanning electron microscopy; x-ray microanalysis of extraterrestrial materials, ferrous alloys, geological materials and ceramics using the electron probe microanalyzer; transmission and scanning transmission electron microscopy studies of grain boundaries in oxides; discontinuous precipitation in non-ferrous alloys; low-temperature phase transformations in iron materials; inclusions in weld structures of ferrous alloys; and glass metal reactions in lunar samples.

**Ceramics.** Microstructure and solid state chemistry of electronic and electro optic oxides including both polycrystalline and single crystalline materials; degradation mechanisms in ceramic devices; deformation mechanisms, including creep and hot pressing; sintering studies and additive effects; microstructural characterization of ceramic materials.

Characterization of metal oxide films using optical and electrical methods emphasizing metal-insulator-semiconductor structures; defect structure and impurity interactions in amorphous and crystalline materials in both bulk and thin-film form; interfacial segregation and phase formation in metal-oxide systems.

**Mechanical behavior.** Effect of polymer chemistry and molecular structure on fatigue crack propagation (FCP); test frequency sensitivity and fatigue fracture micromechanisms in polymer solids; fracture characteristics of bridge steels; fatigue of weldments; corrosion fatigue crack propagation; metallurgical aspects of FCP in ferrous and non-ferrous alloys; fracture mechanism studies by transmission and scanning electron microscopy.

**Polymers.** Fatigue crack growth and relaxation processes in engineering plastics and composites; structure, morphology and mechanical behavior of interpenetrating polymer networks; thermosetting resins; vinyl polymers; polymers based on renewable resources; permeability and mechanical behavior of membranes, coatings, and filled polymers; novel polymer concrete systems.

**Educational opportunities.** This center facilitates programs of study and research that cross the traditional boundaries of science and engineering curricula, providing a fundamental, broad approach to the field of materials science and technology.

Graduate students participating in the center's program usually receive master of science or doctor of philosophy degrees in the academic discipline of their choice, i.e., chemistry, physics, materials science and engineering, computer science and electrical engineering, etc.; or in an interdisciplinary program such as polymer science and engineering. However, they are expected to pursue coursework related to a broader understanding of materials and to conduct research on an interdisciplinary materials problem in one of the center's four laboratories.

Financial support for graduate students is available through the Materials Research Center by means of research assistantships related to sponsored research programs.

For more information, write to the director, Donald M. Smyth, Whitaker Laboratory 5, Lehigh University, Bethlehem, Pa. 18015.

## The Murray H. Goodman Center for Real Estate Studies

The Murray H. Goodman Center for Real Estate Studies was established in 1988 through a major gift from Murray H. Goodman, '48. The center is a self-supporting, interdisciplinary unit of the College of Business and Economics. The center provides financial support and other assistance for undergraduate courses in real estate and real estate finance, supports scholarly research in real estate, and sponsors joint activities with practitioners in the real estate field.

**Educational opportunities.** The center provides resources for teaching undergraduate courses in real estate and real estate finance. Sponsored courses include FIN 298 - Introduction to Real Estate and FIN 398 - Real Estate Finance (to begin in 1990). In addition, the center sponsors a continuing series of seminars and presentations by real estate executives and practitioners. The center also serves as a clearinghouse for students seeking internships with real estate firms and related companies.

**Research activities.** Consistent with the university's encouragement of scholarly research, the center provides funding for faculty research in the real estate area. Funding possibilities include: summer faculty research grants; travel, telephone and administrative support; and grants for part-time graduate assistants. The center also maintains a file of sponsored research opportunities available through private foundations, government agencies and practitioner organizations and provides administrative support to faculty applying for such funding.

**Practitioner Interaction.** The third aspect of the center's activities is its interaction with practitioners in the real estate field. The increased emphasis on continuing education and research among real estate practitioner organizations, as well as Lehigh's proximity to major real estate markets, enable the center to engage the practitioner community in a variety of joint projects. These joint projects include: 1. sponsored research projects; 2. continuing education programs and short courses; 3. special conferences and events of national and/or regional interest; and, 4. center-sponsored databases and continuing activities of interest to the practitioner community.

For more information, write to Stephen F. Thode, Director, Murray H. Goodman Center for Real Estate Studies, Drown Hall 35, Lehigh University, Bethlehem, PA 18015, or call (215) 758-3440.

## Musser Center for Entrepreneurship

The Warren V. Musser Center for Entrepreneurship has been established through a generous grant from 'Pete' Musser, Lehigh class of 1949, for the promotion of entrepreneurship among the students and friends of Lehigh University. Mr. Musser, chairman and CEO of Safeguard Scientifics, Inc., is a highly successful entrepreneur in his own right and an active supporter of entrepreneurial ventures by others. Creation of the Musser Center at Lehigh caps more than a decade of university activities dedicated to encouraging and recognizing the role of entrepreneurship in the American business system. The center enables Lehigh to provide new levels of support for the entrepreneurial spirit.

**SBDC.** The primary activity of the Musser Center for Entrepreneurship is the Small Business Development Center. Established in 1978, the SBDC provides general management assistance to over one thousand entrepreneurs and small businesses per year in the Lehigh Valley and surrounding areas. Primary funding for this program comes from a major grant from the U.S. Small Business Administration and the Commonwealth of Pennsylvania. The Musser Center provides supplemental support for the efforts of the SBDC and contributes monies to enhance its mission and broaden its scope.

**Specialized programs.** The International Trade Development Program is a specialized outreach effort of the Small Business Development Center. The ITDP helps companies with exportable products to develop export marketing plans and establish direct contacts with international markets. Seminars, trade missions and research projects support the efforts of this program. The Government Marketing Assistance Program assists potential suppliers to government in identifying and developing government contracts. Opportunities for marketing to prime contractors are also promoted. Contract administration and general business assistance related to government procedures are handled on a one-to-one basis. Trade fairs and seminars are also offered.

The Financing Assistance Program provides assistance in loan packaging and financial planning and helps clients identify appropriate financing sources. Contracts with the Lehigh/Northampton Revoling Loan Fund, the Bethlehem Economic Development Corporation and other funding agencies provide resources for this assistance.

**LUMAC.** The Lehigh University Management Assistance Counseling program (a graded three-credit course) was established in 1972 on the initiative of undergraduate students. Through support from the SBDC, approximately one hundred, fifty students per year gain practical experience by providing counseling to sixty businesses.

**ACE.** The enrichment of entrepreneurship programs at Lehigh is accomplished in part by the Association of Collegiate Entrepreneurs. Through ACE, students meet entrepreneurs and promote new ventures.

**LEAP.** A related program is the Lehigh Entrepreneurial Associates Program. Leap reaches entrepreneurs currently active in the regional business community. It serves as a forum and educational resource for those interested in extending their entrepreneurial reach.

**SCORE.** The Service Corps of Retired Executives is another affiliate of the Musser Center. SCORE, which works most closely with the SBDC, is chartered by the U.S. Small Business Administration and provides business expertise to current or potential business owners.

**Entrepreneur in residence.** The LU Entrepreneur in Residence is an active entrepreneur and former CEO of his own multi-million dollar company serving full-time on the staff of the College of Business and Economics. This experienced executive teaches courses on entrepreneurship and counsels students and entrepreneurs on their business plans, management teams and operating activities.

**Liaison.** Funding from the Musser Center assists other Lehigh University entrepreneurial activities. In conjunction with the Center for Innovation Management Studies, funding is provided for the Entrepreneur's Roundtable. The Martindale Center for the Study of Private Enterprise uses funding to support student publications. The Center for Economic Education develops curricular materials for secondary school instruction on entrepreneurship. The Musser Center also conducts studies on the problems of business formation and operation and the characteristics of entrepreneurs.

For more information, write to the center's director, John W. Bonge, Musser Center for Entrepreneurship, 301 Broadway, Bethlehem, PA 18015.

## Rauch Center for Business Communications

The Rauch Center for Business Communications was established in 1981 to help present and future managers to express clearly their ideas and decisions in both written and oral form. The center was established with a gift from Philip Rauch '33, who is a retired chairman of the board of Parker Hannifin Corporation.

The center's top priority is to help students improve their competence in written and oral presentation, as it affects the operation and management of a business organization. Elective courses, offered for both undergraduate and graduate students, stress the process of communicating to create documents and business presentations that reflect a purpose. Ultimately, students develop a personal communication style that enables them to adapt to any managerial situation.

The Rauch Center also offers workshops for faculty, students, professional staff and business groups. For the business community, the center conducts seminars for managers and professionals in a wide range of fields, from business and government to health care and education.

In support of the Writing Requirement Program in the College of Business and Economics, the center operates the Business Writing Clinic. Students can drop by any time during business hours for counseling on writing projects. Established through a grant from the General Electric Foundation, the clinic is staffed by undergraduate and graduate students selected for writing mastery in business communication classes.

For more information, write the Rauch Center for Business Communications, Drown Hall 35, Lehigh University, Bethlehem, PA 18015.

## Sherman Fairchild Center for Solid-State Studies

Although work in other aspects of solid-state is carried out in many locations on the Lehigh campus, the Sherman Fairchild Laboratory provides the focal point for studies of electronic materials and devices. Opened in the fall of 1976, the building provides offices and laboratories for an interdisciplinary staff consisting of faculty from the departments of physics, chemistry, metallurgy/materials engineering, and electrical and computer engineering.

**Research activities.** A central theme involving the nature and role

of defects in insulators and semiconductors runs through the research program. Areas of study include quantum theoretical predictions of electronic properties, fabrication of materials and devices for the study of material processing; the elucidation of fundamental electronic, optical and transport behavior; design, fabrication and characterization of novel electronic devices. The research has a current emphasis on silicon, silicon oxides and silicon-related technology, but also includes work on compound semiconductors; complex insulators such as niobates and titanates, and high-temperature ceramic super conductors.

Central to the functioning of the research program is the Microelectronics Research Laboratory, which provides processing facilities for the fabrication of CMOS, CCD, MNOS, bipolar devices and integrated circuits. Available technology includes low-pressure chemical vapor deposition (LPCVD), RF metallization, plasma chemistry, photolithography, ion implantation, high pressure oxidation, and standard oxidation and diffusion. Design of circuits and devices is aided by an Applicon Color Graphics VLSI system, and a HP-IB system permits automatic data acquisition and analysis of device characteristics.

A 3 MeV Van de Graaff accelerator provides a radiation facility that can be used to produce electrons for the generation of point defects or positive ions for the analysis of samples—Rutherford Back scattering and proton-induced X-ray emission (PIXE). Individual laboratories provide instrumentation for studies of ceramic materials fabrication, transport properties, optical excitation and luminescence, electron tunneling, electronic conduction and trapping, electron paramagnetic resonance (EPR) and optical detection of magnetic resonance (ODMR), deep level transient spectroscopy (DLTS).

Current research programs include (1) fundamental radiation damage processes in silicon, an experimental and theoretical program aimed at unraveling the fundamental properties of simple lattice point defects in silicon; (2) a study of the electronic and vibronic structure of intrinsic lattice defects in compound semiconductors, an experimental study of the fundamental properties of simple crystalline point defects in the compound (II-VI, III-V) covalent semiconductors; (3) point defects in insulating solids, experimental studies and theoretical calculations on electron/hole transport, trapping and defective properties; (4) tunneling in MIS memories, an exploration of the dominate physical process in nonvolatile semiconductor memories, namely tunneling of carriers into and through an insulator; (5) VLSI microelectronics, a study of the characterization of small-geometry solid-state devices for VLSI, with emphasis on CMOS transistors; (6) semiconductor charge transport devices, a study of novel device and sensor structures that evolve charge transport and storage. The characterization and modeling of MNOS nonvolatile memory structures; (7) microstructure of electronic materials, microstructural studies of electronic devices, passive components and processing materials to elucidate fundamental mechanisms that govern device performance, to improve device performance and explore novel methods of fabrication.

**Educational opportunities.** Graduate students in the field of solid-state science and engineering usually enroll for the master of science or doctor of philosophy degree in the traditional discipline of their choice, such as physics, metallurgy and materials engineering, electrical engineering, etc., with specific course requirements and research participation coordinated through the appropriate department chairperson. Students are financially supported by graduate fellowships and undergraduate scholarships provided by the Sherman Fairchild Foundation and/or by university sources. In addition, teaching assistantships are available through the departments and a number of research assistant positions are supported by research grants and contract awards obtained by the laboratory staff. All of these arrangements typically permit graduate students in the solid-state studies to undertake three courses per semester in addition to their teaching or research activities.

For more information, write to Ralph J. Jaccodine, director, Sherman Fairchild Center for Solid-State Studies, Sherman Fairchild Laboratory 161, Lehigh University, Bethlehem, Pa. 18015.

## Small Business Development Center

(see Musser Center for Entrepreneurship)

## Technology Studies Resource Center

The Technology Studies Resource Center, based in the College of Arts and Science, creates and disseminates materials and programming that will lead a wide range of people to an understanding of the mutual interaction of technology, and social institutions and values. Through the center, academics from all disciplines can collaborate on research and develop educational opportunities in technology studies with academic colleagues and with non-academic sponsors.

The Technology Studies Resource Center's activities embrace the needs of academics, pre-college and college students, and industrial, political, and public audiences, who seek information about technology as a force in contemporary society. Four principal areas for activities are the development and dissemination of resource materials, professional development programming, educational programming, and stimulation and coordination of technology studies and research projects. Specific activities include: collecting and distributing college-level course syllabi in technology studies; publishing bibliographies in specific areas of technology studies; sponsoring a regional colloquium in technology studies and publishing its best presentations in a working papers format; editing the continuing series RESEARCH INTECHNOLOGY STUDIES; publishing the SCIENCE, TECHNOLOGY, AND SOCIETY CURRICULUM DEVELOPMENT NEWSLETTER; maintenance of a data base of personnel, curricula, and materials resources in technology studies; sponsoring conferences, workshops, seminars and institutes in technology studies; and integrating technology studies material with existing high school curricula and developing better courses in science and mathematics in cooperation with regional administrators and faculty.

For more information write to Stephen H. Cutcliffe, Maginnes Hall 9, Lehigh University, Bethlehem, Pa. 18015.

## Zettlemoyer Center for Surface Studies

The Zettlemoyer Center for Surface Studies was established on February 1, 1966. The center has been successful in fostering interdisciplinary research in a broad range of surface-related phenomena including lipid membrances catalysis, corrosion, environment-enhanced cracking in alloys, coatings, dispersions, printing inks, and colloids. Faculty members from the departments of chemistry, chemical engineering, mechanical engineering and mechanics, and materials science and engineering are associated with the center. The center develops and maintains research facilities, including laboratory and office space, and major experimental equipment used in surface-related research. The center facilitates interchanges of ideas and interactions between faculty and students from different disciplines, thereby nurturing research at the forefront of science and broadening the educational opportunities for graduate as well as undergraduate students.

Financial support for the center comes largely from research projects contracts with various industries and governmental agencies.

The center is well equipped with specialty instrumentation needed for advance research in its field. Sinclair Laboratory houses equipment for experimental studies employing flash desorption, Moessbauer spectroscopy, Auger spectroscopy, laser Raman spectroscopy, X-ray photoelectron spectroscopy, electron spectroscopy for chemical analysis, nanosecond fluorescence spectroscopy, ellipsometry, computerized spectrophotometry, microelectrophoresis, and continuous electrophoresis.

Other specialty equipment includes microbalances, testing machines for studies of environment-affected crack growth, gas adsorption and heat of immersion apparatus, wetting balances, apparatus for determining rheological properties, and apparatus for the preparation of reproducible dispersions and films.

**Research activities.** The center's research program includes a broad range of topics vital to modern science and technology.

Some of the active topics are: solid-state chemistry of catalysts; catalytic oxidation of methane; mechanisms of catalytic reactions and development of new catalysts; surface magnetic properties; wetting of multiphase systems; monodisperse oxides, characterization of surfaces; microelectrophoresis and continuous electrophoresis;

electrophoresis under microgravity conditions; Moessbauer spectroscopy of surfaces; erosion and wear, chemical composition of surfaces; passivity and corrosion inhibition; Auger spectroscopy; chemistry of fracture surfaces, hydrogen embrittlement; environmentally affected crack growth; high-temperature corrosion; adhesion of coatings; corrosion under coatings; chemical state of ions in polymers; charge transport through organic coatings; effect of metallic cations on corrosion processes; water-based coating; electrical properties of coatings; polymer surfaces; research in National Printing Ink Research Institute (NPIRI) related to lithographic, flexographic and gravure printing; rheology in non-Newtonian fluids; adhesion and flow of fluids in porous substrates; and chemistry and metallurgy of galvanized steel.

**Educational opportunities.** The center is a facility in which graduate students undertake dissertation research leading to the M.S. or Ph.D. degrees in existing science and engineering curricula. Pertinent courses are offered in the departments of chemistry, chemical engineering, physics, mathematics, biology, materials science and engineering, and mechanical engineering and mechanics.

Potential and current graduate students whose interests are consistent with the center's objectives are welcome to associate with the research program and to avail themselves of the experimental facilities. Research assistantships are available. Since research topics are selected by mutual agreement, interested students are encouraged to explore research opportunities with the center's director.

The center's research also forms the basis of continuing educational programs designed primarily for industrial personnel. The conference center in Sinclair Laboratory accommodates the special seminars and short courses that are held periodically. Recent course topics include corrosion, printing ink technology, adhesion, and surface and colloid science.

The center provides opportunities for resident postdoctoral studies and for visiting scientists.

For more information, write to the director, Gary W. Simmons, Sinclair Laboratory 7, Lehigh University, Bethlehem, Pa. 18015.

# Organizational Headquarters for Applied Technology

## Ben Franklin Advanced Technology Center

The Northeast Tier Ben Franklin Technology Center (NET/BFTC), based in the Ben Franklin Building on the Murray H. Goodman Campus, was established in 1983 as part of the Commonwealth of Pennsylvania's Ben Franklin Partnership program. It is an economic development program of the State Department of Commerce.

The Partnership program aims to combine the resources and expertise found throughout the state's educational system with business's technology-advancement efforts to create products and improve manufacturing processes and productivity. Through these efforts, the Ben Franklin program serves to diversify the state's economy, thus creating and retaining jobs in Pennsylvania. The center at Lehigh is one of four centers in the state working with business, education and government toward these goals; the other centers are based at the University City Science Center, Philadelphia; Pennsylvania State University, University Park; and Carnegie-Mellon University/University of Pittsburgh.

The NET/BFTC works with a consortium that includes more than 1000 companies, 84 schools and 107 community, government and other organizations in northeastern Pennsylvania. Its goals include helping new technology-oriented businesses to form and grow, helping existing manufacturers to improve productivity through new technologies and practices, and serving as a catalyst for related economic development activities in the region. Technical and business assistance services are provided on a year-round basis. The center also encourages the development of business incubator centers and supports the development of education and training programs that meet the needs of industry.

For the 1988-89 funding year, the NET/ATC received $6.7 million from the state Department of Commerce and $21 million in matching funds from private-sector businesses, educational institutions and other sources. The NET/ATC has over 70 projects with Lehigh, involving approximately 200 faculty members, research scientists, project engineers, students, technicians, and administrative staff.

For more information, contact Mark S. Lang, executive director, Ben Franklin Center, 125 Goodman Drive, Lehigh University, Bethlehem, Pa. 18015-3715; (215) 758-5200.

## Council on Tall Buildings and Urban Habitat

The Council on Tall Buildings and Urban Habitat, an international activity sponsored by engineering, architectural, and planning professionals, was established in 1969 to study and report on all aspects of the planning, design, construction, and operation of tall buildings.

The council's seven professional society sponsors are: International Association for Bridge and Structural Engineering, American Society of Civil Engineers, American Institute of Architects, American Planning Association, the International Union of Architects, The American Society of Interior Designers, and the American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc. In 1974 the council was admitted as a consulting nongovernmental organization to United Nations Educational, Scientific and Cultural Organization under Category C. In 1979 it was upgraded in its interactions with UNESCO to Category B.

The council is concerned with the impact of tall buildings on the urban environment and in the role they play in urban life. This involves a systematic study of the problem of providing adequate space for life and work, considering not only technological factors, but social and cultural aspects as well. Important activities include the identification and stimulation of needed research and implementation of findings into codes, specifications, and standards.

The seven groups that carry out the major activities of the council are Planning and Environmental Criteria for Tall Buildings (PC); Development and Management (DM); Tall Building Systems and Concepts (SC); Building Service Systems (BSS); Tall Building Criteria and Loading (CL); Structural Design of Tall Steel Buildings (SB); and Structural Design of Tall Concrete and Masonry Buildings (CB).

A major focus of the council is a comprehensive multi-volume monograph on the planning and design of tall buildings. They cover environmental aspects, transportation and other planning aspects; service systems, structural systems; the various loading systems; structural safety, foundations, and structural design methods and limit states—the latter covering both steel and concrete buildings.

The monograph is kept current through a series of monograph update volumes that are released at appropriate intervals. In addition, individual chapters are being revised and separate volumes released as more information becomes available. The council is not an advocate for tall buildings, *per se,* but in those situations in which such buildings are viable, it seeks to encourage the use of the latest knowledge in their implementation.

The headquarters of the council is at Lehigh University. Nearly 1,200 specialists, primarily engineers, architects, planners, and sociologists from seventy countries, are involved in the work of its committees. A number of these committees provide advisory guidance for relevant Lehigh research projects.

For more detailed information, contact Director Lynn S. Beedle, Building 13, Lehigh University, Bethlehem, Pa. 18015.

## Manufacturing Services Extension Center

In 1988, nine Industrial Resource Centers were formed throughout Pennsylvania by the Dept. of Commerce to provide services and resources to small and medium sized manufacturers to help them to

stay competitive. One of these centers, the Manufacturing Services Extension Center (MSEC), is an Industrial Resource Center serving seven counties in Eastern Pennsylvania. MSEC is also a member corporation of Lehigh University.

MSEC offers manufacturers assistance in improving product quality, productivity and profitability. Typical services fall in the following categories: Project management, total quality management, manufacturing and industrial engineering, design for manufacturability, production and process planning, equipment selection/justification, and business management. Resources available through MSEC are experienced MSEC professionals, private consultants, customized training programs, library of manufacturing materials and access to data bases.

Additionally, four technical demonstration sites have been established where manufacturers are able to observe, learn and try new technologies. These sites are located at Lehigh University, Albright College, East Stroudsburg University, and Northampton County Community College.

MSEC has three manufacturing consultants to act as project managers to the client as they work with a network of private consultants. For more information about the services MSEC offers, contact Edith Ritter, Executive Director at (215) 758-5599.

## Structural Stability Research Council

The Structural Stability Research Council (formerly Column Research Council) was founded in 1944 by the Engineering Foundation to review and resolve the conflicting opinions and practices that existed at that time with respect to solutions to stability problems, and to facilitate and promote economical and safe design. The Council has been headquartered at Fritz Engineering Laboratory since 1966.

At the core of the council's activities are 17 task groups and 8 task reporters. At its Annual Technical Session, a forum is provided whereby the latest research results pertaining to these groups are presented. This represents a primary source of the highlights of the latest solutions to structural problems before they are eventually published in technical journals.

The Council offers guidance to specification writers and practicing engineers by developing both simplified and refined calculation procedures for the solution of stability problems, and assessing the limitations of these procedures. The Council's major publication is the *Guide to Stability Design Criteria for Metal Structures*. Now in its fourth edition, this book is the most comprehensive treatment available anywhere in the world on stability problems associated with metal structures.

The international membership of the council is made up of representatives from governmental and private organizations concerned with specifications and design procedures for metal structures, representatives of consulting firms engaged in engineering practice, members-at-large selected from universities and design offices, and corresponding members from various countries who are in touch with stability research in their region.

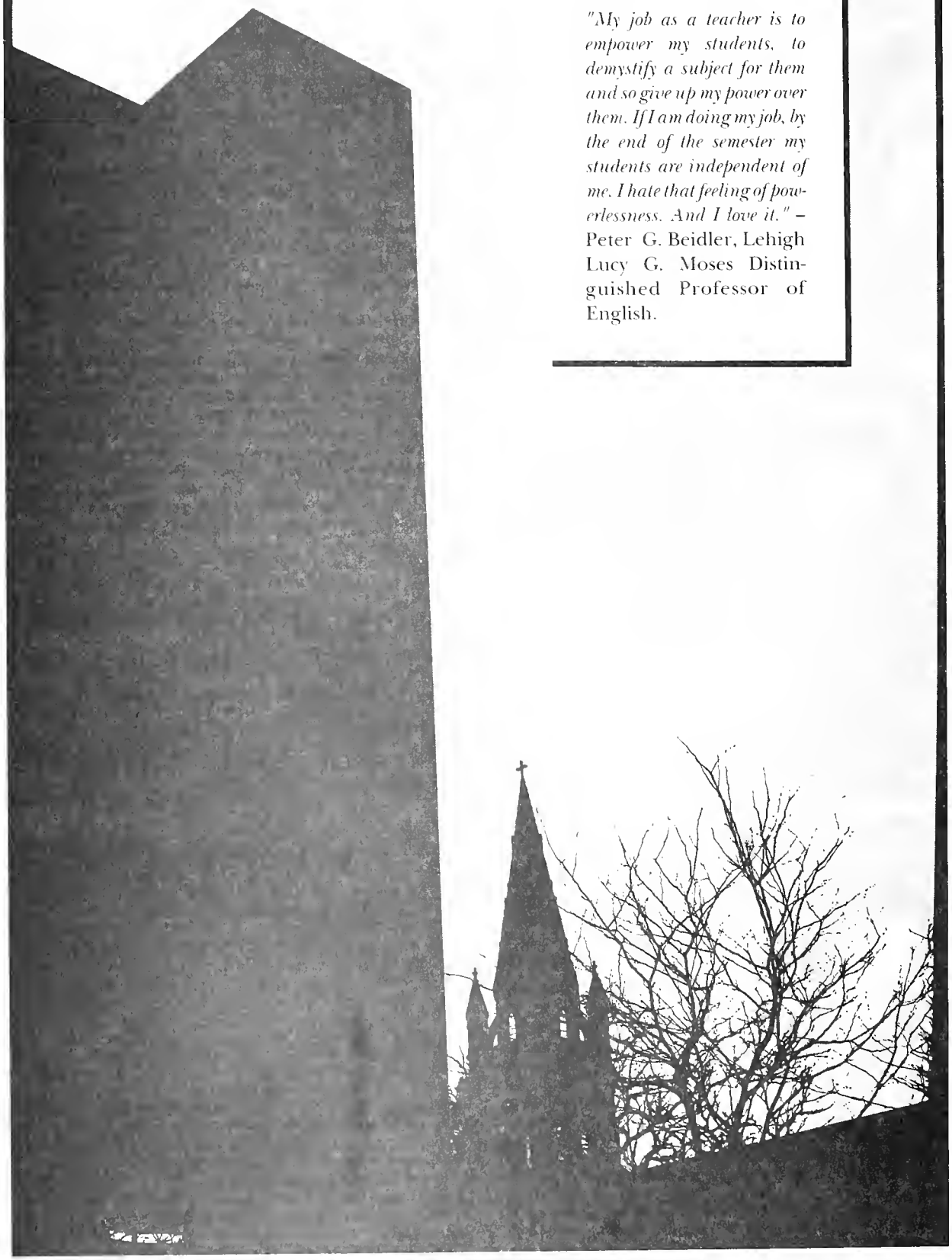
Many former Lehigh University graduate students and research workers are now active members of the council. A number of Fritz Engineering Laboratory research projects have received the guidance of the Council's advisory committees.

For more detailed information, contact Dr. Lynn S. Beedle, SSRC Director, Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa. 18015.

# V

## Descriptions of Courses

*"My job as a teacher is to empower my students, to demystify a subject for them and so give up my power over them. If I am doing my job, by the end of the semester my students are independent of me. I hate that feeling of powerlessness. And I love it."* – Peter G. Beidler, Lehigh Lucy G. Moses Distinguished Professor of English.



# V.

# Descriptions of Undergraduate and Graduate Courses

This section includes listings of undergraduate and graduate courses offered by Lehigh University. For purposes of record, all approved courses are listed. It must be understood, however, that the offerings in any given semester are contingent upon a number of factors, including student needs as determined at the time of preregistration.

All academic departments are listed in alphabetical order across the page.

## *Credit Hours*

The number in parentheses following each course title indicates the credit value of the course in terms of semester hours ("credit hours"). Three hours of drawing, of work in the laboratory, or of practice in the field are regarded as the equivalent of a recitation or lecture of one hour's duration.

## *Course Numbering*

The course numbering system specifies which courses can be applied to the program of study as the student progresses toward the undergraduate or graduate degree. In general, the numbering series is as follows:

**0-99.** Courses primarily for freshmen or sophomores. Not available for graduate credit.

**100-199.** Intermediate-level undergraduate courses. Not open to freshmen except on petition. Not available for graduate credit.

**200-299.** Advanced undergraduate courses. Courses in the College of Business and Economics and specific departments as noted in the listings are open to freshmen and sophomores only on petition. Not available for graduate credit in the major field.

**300-399.** Same as 200-299, but available for graduate credit in major field.

**400-499.** Graduate courses, open to undergraduates only by petition.

## *Provisional Courses*

Each instructional department is authorized to offer provisional courses, or those offered on a trial basis, as well as special opportunities courses. Such courses can become a permanent part of the university curriculum. These courses are numbered, as is appropriate, . . 95-98 . . 195-198, . . . 295-298, . . . 395-398, for a maximum of two semesters.

Students may take 95-98 series courses pass/fail under the standard procedures for pass/fail.

## *Apprentice Teaching and Cooperative Undergraduate Education*

For details of these programs, see descriptions under "Apprentice Teaching" and "Cooperative Undergraduate Education," listed alphabetically in this section.

## *Prerequisites*

Academic preparation required for admission to courses is indicated under "prerequisites" included at the end of each course description. Prerequisites are stated in most cases for purposes of convenience in terms of Lehigh courses. Academic status required for admission, where numbering does not fully describe this status, is also indicated under "prerequisites."

A student who does not have the status (e.g., sophomore standing) or the academic preparation set forth as prerequisites must, in order to be admitted to a course, file with the registrar at the time of registration and on a standard form provided, a waiver of prerequisites signed by the course instructor, the teaching department chair and either the chair of the student's major department or the associate dean. Academic work completed elsewhere must be attested in this manner as being substantially equivalent to prerequisites listed, unless the student's records in the Office of the Registrar show that the proper officers have so evaluated this preparation previously.

Engl 2, 4, 5, 6, 8, 10 or 12 are prerequisites to all 100- or higher-level courses. Exceptions may be made only by petition to the Committee on Standing of Students.

In a few cases, corequisites are indicated. In such instances the corequisite course is taken in the same semester.

## *Abbreviations*

Whenever possible, course listings contain information indicating what requirements the course satisfies, the semester or semesters in which it is offered, and the name of the scheduled instructor or instructors.

While all information herein is subject to change, the information is included to serve as a guide in the selection of appropriate courses that best fulfill the student's academic requirements and personal goals.

The symbols following course titles for some College of Arts and Science courses include:

**NS.** Psychology department courses that meet the Natural Science distribution requirements.

**SS.** Psychology department courses that meet the Social Science distribution requirements.

## *Chemistry and Physics*

Effective July 1, 1987, the departments of chemistry and physics, traditionally associated with the College of Engineering and Applied Sciences, joined other science departments administered within the College of Arts and Science. Reflecting the change, the former became known as the College of Engineering and Applied Science. Because the change is primarily related to the university's organization, students enrolled in chemistry and physics will not be significantly affected in their course work.

## *Status of Divisions*

A number of areas of study are listed independently of the parent

department's entry. For example, astronomy, taught in the mathematics department, is listed under Astronomy. Similarly, courses offered by divisions of departments are listed alphabetically rather than with the department entry. A number of language courses are listed under the entry for the department of modern foreign languages, rather than alphabetically.

### *Faculty Identification*

In many cases, the names of professors scheduled to teach a course are listed at the conclusion of the course description entry. In most instances, those identified in this way are listed as faculty members in the introductory section to each department. In a few cases, however, the teacher may be associated with another department. In any case, identification of the individual and his or her credentials may be found in the alphabetical listing of faculty members in Section VII.

### *Information Limits*

The course descriptions are intended to guide the student in selecting appropriate courses. For reasons of space, descriptions are brief. In most cases, courses will have a significantly broader scope than the topics listed in the description. In some courses, material may change from what is described. If there is doubt concerning the appropriateness of any course for the individual's educational objectives, it is suggested that the student confer with the adviser.

### *A Choice of Titles*

Note: Principal officers of academic departments are identified as *chairpersons* in most cases. Individuals who prefer to be known as *chairmen* are identified accordingly. The responsibilities are identical regardless of which term is used.

# Accounting

**Professors.** James A. Largay, III, Ph.D. (Cornell), *C.P.A., Arthur Andersen & Co. Alumni Professor of Accounting;* Frank S. Luh, Ph.D. (Ohio State); Robert H. Mills, Ph.D. (Wisconsin), *C.P.A.;* Kenneth P. Sinclair, Ph.D. (Massachusetts), *chairman.*
**Associate professors.** D. Raymond Bainbridge, Ph.D. (Lehigh), *C.P.A.;* James A. Hall, Ph.D. (Oklahoma State), *Deloitte Haskins & Sells Information Systems Fellow;* John W. Paul, Ph.D. (Lehigh), *C.P.A.;* Stuart K. Webster, Ph.D. (Iowa), *C.P.A.*
**Assistant professors.** Michael L. Davis, Ph.D. (Massachusetts), *C.P.A., Peat Marwick Main Research Fellow;* Parveen P. Gupta, Ph.D. (Penn State); John Kercsmar, Ph.D. (Houston), *C.P.A.;* Robyn Lawrence, Ph.D. (Houston); John J. Maher, Ph.D. (Penn State).
**Instructor.** Manash R. Ray, M.B.A. (Calcutta).

The Department of Accounting offers a wide variety of courses in accounting which: support the College of Business and Economics core requirements; provide an undergraduate major in accounting; are elective courses for other College of Business and Economics undergraduate majors; and form a key component of the Master of Business Administration program. The upper-level undergraduate courses have a professional accounting orientation which continues to sustain a large enrollment in the accounting major. Within the major, there is the opportunity to explore the various career opportunities within the broad field of accounting: financial, managerial, taxation, auditing, and information systems.

### *Objectives of the Accounting Program*

The primary goals of Lehigh's undergraduate program leading to the Bachelor of Science degree in Business and Economics with a major in accounting are to:

Cultivate an inquiring mind and kindle the student's interest in lifelong learning

Subject the student to a rigorous academic program in the liberal arts in addition to business and economics

Provide the student with a theoretical framework as well as problem-solving skills in each of the following areas in accounting: financial, managerial, information systems, auditing, and taxation

Encourage the development of interpersonal skills including oral and written communication skills

Promote self-development through participation in extracurricular and social activities.

To the extent the above objectives are achieved, the graduate is prepared for the following: an entry level position in industry, not-for-profit organizations, public accounting; self-employment; and graduate studies. This academic program prepares interested students for relevant professional accounting examinations.

## The Accounting Major

The undergraduate program in accounting is accredited (Type A) by the American Assembly of Collegiate Schools of Business. This achievement places the program within a small group of schools nationally which have satisfied a rigorous examination of the program, faculty, and students beyond the accreditation standards applied to the College of Business and Economics undergraduate and graduate programs.

The program is offered in the College of Business and Economics. Required: 18 credit hours beyond core requirements.

| | |
|---|---|
| Acct 307 | Fundamentals of Federal Income Taxation (3) |
| Acct 311 | Accounting Information Systems (3) |
| Acct 315 | Financial Accounting I (3) |
| Acct 316 | Financial Accounting II (3) |
| Acct 320 | Fundamentals of Auditing (3) |
| Acct 324 | Cost Accounting (3) |

## Undergraduate Courses in Accounting

**51. Introduction to Financial Accounting (3)**
The organization, measurement and interpretation of economic information. Introduction to accounting theory, concepts and principles, the accounting cycle, information processing, and financial statements. Exposure to controversial issues concerning income determination and valuation. Prerequisite: sophomore standing.

**52. Introduction to Managerial Accounting (3)**
An introduction to internal accounting information for all levels of management. Topics include cost flow in a manufacturing operation; planning, evaluating and controlling through budgeting and standard costing; and decision-making using cost-volume-profit analysis, direct costing, and relevant costs. Prerequisite: Acct 51.

**108. Fundamentals of Accounting (3)**
A one-semester survey of accounting principles and practices, including an introduction to industrial cost systems designed for those students planning to take only one accounting course. Other students should take the Acct 51-52 sequence.

**111. Management Information Systems in Business (3)**
An introduction to information systems with an emphasis on business applications. Students develop a working knowledge of a computer language sufficient to solve business problems. Basic knowledge of hardware, software, computer systems, and the systems development process. File organizations, the data base concept and distributed data processing systems are covered. Prerequisite: Mgt 1.

## Advanced Undergraduates and Graduate Students

**307. Fundamentals of Federal Income Taxation (3)**
An introductory study of the principles and concepts of federal income taxation of individuals, corporations, partnerships, and fiduciaries; and federal gift and estate taxes. Determination of tax liabilities and opportunities for planning are emphasized. Problem-solving using the source materials of tax law and tax research are important components of the course. Prerequisite: Acct 51.

**309. Advanced Federal Income Taxation (3)**
An advanced study of the taxation of business organizations, estates, trust, and wealth transfer taxes. Planning and research are the basic components of the course. Problem-solving and written research are emphasized. Prerequisite: Acct 307

**311. Accounting Information Systems (3)**
An introduction to the concepts underlying information systems as they relate to organizational structure, managerial decision making and accounting. The course acquaints students with the reports and documents generated by information systems, as well as procedures and controls employed in a variety of business applications. Students apply these concepts, techniques and procedures to the planning, analysis and design of manual and computer based information systems. Prerequisites: Acct 52 and 111.

**315. Financial Accounting I (3)**
Intensive study of the basic concepts and principles of financial accounting, emphasizing the problems of fair presentation of an entity's financial position and operating results. Consideration of the conceptual framework of accounting, review of the accounting process, and measurement and valuation of current assets, current liabilities, plant assets, intangibles, investments, and long-term debt. Problem-solving skills and critical analysis are stressed. Prerequisite: Acct 52.

**316. Financial Accounting II (3)**
The sequel to Accounting 315, this course continues with intensive study of such topics as stockholders' equity, valuation and disclosure of leases and pensions, income tax allocation, changing prices, revenue issues, earnings per share, and complexities related to the statement of changes in financial position. Analysis and interpretation of financial statements and problem-solving skills are integral parts of the course. Prerequisite: Acct 315.

**317. Advanced Financial Accounting (3)**
A study of specialized topics in financial accounting, including partnership accounting, business combinations and consolidated financial statements, segment and interim reporting, foreign currency transactions and translation, and accounting and reporting for governmental and other nonprofit organizations. Involves considerable problem-solving and critical evaluation of controversial theoretical issues. Prerequisite: Acct 315 or 316.

**320. Fundamentals of Auditing (3)**
An introduction to auditing theory, objectives, and practices related largely to the responsibilities of independent professional accountants. The auditing environment, generally accepted auditing standards, internal control theory, and reporting alternatives are considered. Exposure to operational auditing is provided. Prerequisites: Acct 311 and 315.

**324. Cost Accounting (3)**
An in-depth study of cost concepts appropriate for product costing in a manufacturing operation, planning and controlling routine operations, and nonroutine decision-making. Topics include job order and process costing, joint and by-products, cost allocation, budgeting, standard costing, direct costing, cost-volume-profit analysis, and relevant costs for decisions. Prerequisite: Acct 52.

**371. Directed Readings (1-3)**
Readings and research in various fields of accounting; designed for superior students who have a special interest in some topic or topics not covered by the regularly rostered courses. Written term paper(s) required. Prerequisite: preparation acceptable to the department chairperson.

**372. Special Topics (1-3)**
Special problems and issues in accounting for which no regularly scheduled course work exists. When offered as group study, coverage varies according to interests of the instructor and students. Prerequisite: preparation in accounting acceptable to the department chairperson.

**390. Internship (1-6)**
Designed to give advanced students of accounting, who have maintained a satisfactory standard of scholarship and who show promise in the field of accounting, an opportunity to acquire field experience and training with selected industrial or public accounting firms or governmental agencies as a complement to the academic learning process. Outside readings are assigned. Written reports are submitted by students and a performance evaluation is made by the employer. The amount of credit is influenced by the length of the training period. Prerequisite: junior standing and approval of the faculty committee on internship.

## Graduate Courses in Accounting

Undergraduates may wish to plan a program that includes the M.B.A. degree as part of the professional accounting preparation. For information about C.P.A. requirements in different states, the C.M.A. certificate, or for the selection of accounting electives, consult the department chairperson.

**403. Financial Flows and Accounting Measurements (3)**
Corporate financial reporting: identification, accumulation and communication of financial information to management and other users. Generally accepted accounting principles, uses and limitations of accounting information, asset valuation, income determination, funds flows, and analysis and interpretation of financial statements.

**413. Managerial Accounting and Decision-Making (3)**
Cost accounting techniques for management planning and control. Responsibility accounting, budgeting, cost behavior, cost estimating, and allocation, product costing, relevant costs, cost variance analysis, information requirements. Prerequisite: Acct 403 or equivalent.

**421. Information Systems for Managers (3)**
Information processing, computer, and data structure concepts in producing information. Communications between user management and data processing management in the systems development process. Control of systems development activities, data based systems, and distributive processing systems. Projects and case studies. Prerequisites: Mgt 413 (or concurrently) and Acct 403.

**431. Accounting Theory and Thought (3)**
Critical and historical examination of modern accounting concepts. Measurement, communication, and interpretation of enterprise income, capital, and related economic data. Prerequisite: 15 credit hours of accounting.

**433. (IE 408) Management Information Systems (3)**
Integrated and total systems concepts for organizational data bases and information systems as applied to planning, development and implementation of computer-based management information systems. Emphasis placed on the interaction of information systems with management planning and control. Prerequisite: an advanced course in information systems and a knowledge of programming.

**435. Advanced Management Accounting (3)**
Managerial planning and control problems with emphasis on the responsibilities of the accountant. Practical applications using cases. Includes advanced treatment of management control systems, managed costs, transfer pricing, and the capital investment problem. Prerequisite: Acct 413 or a course in cost accounting.

**439. Contemporary Issues in Financial Reporting (3)**
Corporate financial reports from the perspective of the user-analyst: disclosure, price level accounting, foreign currency, business

combinations, leases, and analysis of financial statements. Case studies. Prerequisite: Acct 413.

**471. Directed Readings (1-3)**
An extended study of an approved topic in the fields of accounting. May be repeated.

**472. Special Topics (1-3)**
Special problems and issues in accounting and law for which no regularly scheduled coursework exists. When offered as group study, coverage varies according to interests of the instructor and students. Prerequisite: preparation in accounting acceptable to the department chairman. May be repeated.

# Administration and Supervision

See listings under Education.

# Aerospace Studies

**Professor.** J. William Jahn II, M.P.A. (Auburn University), *chairperson.*
**Assistant professors.** Maj. Patrick A. Keating, MAS (Governors Univ.); Capt. Kenneth J. McArthur, M.B.A. (Missouri); Capt. David P. Pletcher, M.S. (George Washington Univ.).

The Air Force Reserve Officer Training Corps (AFROTC) program at Lehigh was established in 1947. The program is conducted through the department of aerospace studies, which offers two voluntary programs, one of four years and one of two years, for students to qualify for a commission as a second lieutenant in the Air Force.

The general objective of the Air Force program is to instill in each student a basic understanding of associated professional knowledge, a strong sense of personal integrity and individual responsibility, an appreciation of the requirements of national security, and an opportunity to learn and develop leadership ability. The academic courses are available to all Lehigh students whether or not they want a commission.

**Course credit.** Advanced aerospace studies course credit may be substituted for six hours of electives for students in the College of Arts and Science, the College of Business and Economics and the College of Engineering and Applied Science.

## Minor in Aerospace Studies

This program is designed to prepare an individual for commissioning as a second lieutenant in the U.S. Air Force and serve as an Air Force officer upon graduation. It is a required program for any Lehigh student who plans to receive a commission in the Air Force through AFROTC. The minor recognizes two basic needs of Air Force officers: familiarization with mathematical concepts required in the increasingly complex technological environment of national defense, and the officer as a manager and leader who must be able to effectively communicate with others.

The minor in aerospace studies includes the following courses:

| | |
|---|---|
| AF 11, 12 | The Air Force Today (2) |
| AF 13, 14 | The Development of Air Power (2) |
| AF 101 | Field Training (0) |
| AF 113, 114 | Air Force Management and Leadership (6) |
| AF 115, 116 | National Security Forces in Contemporary American Society (6) |
| Engl 1, 2 | Composition and Literature and Literature: Fiction, Drama, Poetry (6) |
| Math 21 | Analytic Geometry and Calculus I (4) |
| | Total credit hours 26 (25) |

Engl 10, 14 or 16 may replace Engl 2.

Math 31 (4 credit hours), Math 41 (3), or Math 388 (3) may replace Math 21. Other mathematical reasoning courses may be substituted with the approval of the department chairperson.

A maximum of six credits in aerospace studies courses may be included in the credits required for graduation.

Advanced credit granted by Lehigh for any of the required courses listed above will be credited toward the minor. A minimum grade of C must be earned in each course for the student to be eligible for designation as a distinguished graduate. The department of aerospace studies monitors the minor.

### *Four-Year Program*

The four-year program consists of classroom and laboratory work during the four undergraduate years and four weeks of field training, usually between the sophomore and junior years, at an Air Force base.

During the General Military Course, the first two years, the program acquaints students with Aerospace history, the mission and organization of the Air Force, including technological advances and current research and development activities. Students also begin leadership training. During the Professional Officer Course, the last two years, the role of the armed forces in American society is examined. Emphasis is placed on personal development as a manager and a leader. Students develop leadership talents and abilities by assuming positions of responsibility in the Cadet Corps.

In addition to completing the required Aerospace Studies courses, General Military Course contract cadets must successfully complete a course in English composition within two academic years. They also are encouraged to take a course in speech during this period. Professional Officer Course cadets must successfully complete a mathematical reasoning course.

### *Two-Year Program*

All requirements for commissioning can be completed in the two-year program. Students may apply for entry if they intend to complete two or more full academic years either undergraduate, graduate, or a combination of both. Prior to formal enrollment, each student successfully completes a six-week summer training period which replaces the General Military Course and the normal four-week summer training. Students in the two-year program also must meet the same English and mathematics requirements as students in the four-year program.

### *Scholarship Program*

Air Force ROTC awards scholarships at the freshman, sophomore and junior levels. They are available to qualified cadets in the two-year and four-year programs. Scholarships are given on a semester basis. The maximum is eight semesters (four years), the minimum four semesters (two years). Scholarships of seven, six and five semesters are also available. The only requirement for scholarship eligibility is enrollment in the Aerospace Studies course. Commitment is not effective until acceptance of the scholarship or entrance into the advanced course. Once awarded a scholarship a cadet continues on scholarship status until completion of the advanced course if all academic and military requirements are met. Scholarships pay tuition (full or partial) and most textbook, laboratory, and incidental fees plus $100 a month nontaxable allowance during the school year. Scholarship recipients are required to complete one full year of a foreign language.

### *Commissioning Requirements*

To be eligible for the Air Force ROTC advanced program (final two years), and commissioning, a student must be a citizen of the United States, physically qualified for commission in the Air Force in accordance with existing Air Force regulations, not under fourteen years of age and, upon graduation, not more than thirty years of age. For those with prior military service, commissioning must occur not later than age 35.

In addition, cadets must pursue work leading to at least a bachelor's degree and be willing to sign a formal agreement at the beginning of the advanced course or upon initiation of a college scholarship. The agreement, an enlistment into the Air Force Reserve, obligates the student to remain in the ROTC program, accept a commission and serve the required period in the Air Force upon graduation.

## Aerospace Studies Courses

**11. The Air Force Today (1)** fall
A study of the doctrine, mission and organization of the U.S. Air Force. A study of tactical and airlift forces, their mission, function, and employment.

**12. The Air Force Today (1)** spring
A study of U.S. strategic offensive and defensive forces, aerospace support forces, and a review of Army, Navy and Marines general-purpose forces.

**13. The Development of Air Power (1)** fall
An examination of the developmental growth of air power from the advent of the air age to the conclusion of World War II by reviewing the various concepts of employment and focusing upon the factors which prompted research and technological change.

**14. The Development of Air Power (1)** spring
A continuation of AF 13 from the conclusion of World War II to the present, with emphasis on a variety of events and elements in the history of air power, especially where these provide significant examples of the impact of air power on strategic thought.

**101. Field Training (0)** summer
In order to receive a commission through Air Force ROTC, a student attends field training, normally during the summer following the sophomore year. Sessions include career and job orientation, organization and function of an Air Force base, junior officer training, physical training, small arms marksmanship, and survival. Travel pay is provided. Students receive approximately $100 per week in addition to room and board.

**102. Advanced Training Program (0)** summer
An honors program, highly recommended but not required to receive a commission. ATP is a two- or three-week orientation program on an Air Force installation, normally taken the summer prior to the final year by those with high academic standing. The program provides specialized career orientation and an opportunity to observe a working Air Force facility. The program provides contact with officers working in the student's specialty. Transportation, lodging and meals are provided in addition to approximately $100 per week.

**Airborne Training Program (0)** summer
Appropriate classroom, physical conditioning, and airborne parachute training (including five controlled parachute jumps) are available through a cooperative Air Force-Army program similar to that offered Air Force Academy cadets. Aerospace studies students volunteering for this course spend the summer preceding their final year in AFROTC. This is not required training. Prerequisite: AF 101.

**113. Air Force Management and Leadership (3)** fall
AF 113 and 114 are integrated management courses emphasizing the individual as a manager in an Air Force milieu. Individual motivation and behavioral processes, leadership, communications, and group dynamics are covered to provide a foundation for the development of the junior officer's professional skills. Organizational and personal values, management of forces in change, organizational power, politics, and managerial strategies and tactics are discussed. Actual Air Force cases are used.

**114. Air Force Management and Leadership (3)** spring
A continuation of AF 113.

**115. National Security Forces in Contemporary American Society (3)** fall
AF 115 and 116 conceptually focus on the armed forces as an integral element of society, with an emphasis on the broad range of American civil-military relations and the environmental context in which U.S. defense policy is formulated and implemented. In each semester, students prepare individual and group presentations for the class, write reports and participate in group discussions, seminars and conferences.

**116. National Security Forces in Contemporary American Society (3)** spring
A continuation of AF 115.

# American Studies

**American Studies Committee.** William G. Shade, Ph.D. (Wayne State), *professor of history and director of American Studies;* Nicholas Adams, Ph.D. (N.Y.U.), *professor of art and architecture;* David Curtis Amidon, Jr., M.A. (Penn State), *lecturer in urban studies;* Peter G. Beidler, Ph.D. (Lehigh), *Lucy G. Moses Distinguished Professor of English;* Joseph A. Dowling, Ph.D. (N.Y.U.), *distinguished professor of history;* Michael L. Raposa, Ph.D. (Pennsylvania), *assistant professor of religion studies;* James R. Frakes, Ph.D. (Pennsylvania), *Edmund W. Fairchild Professor of American Studies;* Edward J. Gallagher, Ph.D. (Notre Dame), *professor of English;* James R. McIntosh, Ph.D. (Syracuse), *professor of sociology;* Howard R. Whitcomb, Ph.D. (S.U.N.Y. at Albany), *professor of government.*

American Studies is an interdepartmental major emphasizing the idea that the institutions and values of a society comprise a whole, not merely the sum of its parts. By concentrating on the unique expressions of individuals contained in both the arts and popular culture and by studying the historical movements and contemporary institutions within which these expressions develop, American Studies reveals relationships that may not be clearly seen within the framework of a single discipline.

The broad interdisciplinary nature of American Studies equips the student with a well-rounded general education and a wide range of career opportunities. The student may choose to emphasize American history or literature to provide an excellent preparation for graduate school in these areas as well as in American Studies. In addition the major can be combined with other majors, such as journalism, or minors, such as Law and Legal Institutions, to furnish a sound underpinning for careers in those areas. With suitable collateral courses, the major also can prepare students for advanced work in museum administration, library science, social work and for teaching in both secondary schools and community colleges.

The major consists of fifteen credit hours of preliminary courses dealing with American literature, history, and popular culture. All students are also required to take two American Studies courses, one at the intermediate level introducing the general approach of the major and a senior seminar on contemporary American civilization. In connection with the director of American Studies, who serves as the adviser for the major, each student chooses a program of fifteen semester hours of upper-level courses drawn from four different groups. The major requirements total 36 credit hours.

**required preliminary courses** (15 credit hours)

| | |
|---|---|
| Hist 9 | Survey of American History I (3) |
| Hist 10 | Survey of American History II (3) |
| Engl 23 | American Literature I (3) |
| Engl 24 | American Literature II (3) |

Choose three hours in the area of American Popular Culture from the following:

| | |
|---|---|
| Engl 63 | Narrative Film (3) |
| Engl 89 | Science Fiction (3) |
| Engl 189 | Popular Literature (1-3) |
| Engl 191 | Special Topics (1-3) |

**required American Studies courses** (6)
Intermediate level: Arts 111, The American Character (3)
Upper-level seminar: Arts 311, Themes in Contemporary American Civilization (3)

**required upper-level courses** (15)
Choose at least six hours each from two groups.

*Literature*

| | |
|---|---|
| Engl 376 | Early American Literature (3) |
| Engl 377 | American Romanticism (3) |
| Engl 378 | American Realism (3) |
| Engl 379 | Twentieth-Century American Literature (3) |
| Engl 380 | Contemporary American Literature (3) |
| Engl 382 | Themes in American Literature (3) |

*History*

| | |
|---|---|
| Rel 53 | Religion and the American Experience (3) |
| Hist 119 | Colonial America (3) |
| Hist 120 | Revolutionary America (3) |
| Hist 325 | American Social History, 1607-1877 (3) |
| Hist 326 | American Social History Since 1877 (3) |
| Hist 327 | American Intellectual History (3) |
| Hist 328 | American Intellectual History (3) |

*Government and Society*

| | |
|---|---|
| Govt 317 | The American Presidency (3) |
| Govt 327 | Socialization and the Political System (3) |
| Govt 351 | Constitutional Law (3) |
| US 321 | White Protestant Americans (3) |
| Soc 141 | Social Deviance (3) |
| Soc 364 | Lifestyle and the Family (3) |
| Soc 370 | Juvenile Delinquency (3) |

*Minorities in America*

| | |
|---|---|
| US 125 | American Ethnic Groups (3) |
| US 328 | The American Jewish Community (3) |
| Engl 311 | Literature of Women (3) |
| Engl 312 | Jewish Literature (3) |
| Engl 316 | The Indian in American Literature (3) |
| Hist 131 | The Black Experience in America (3) |
| Hist 124 | Women in America (3) |
| Anth 182 | North American Indians (3) |

The courses listed here are recommended, but comparable courses in each of these areas may be substituted with written permission of the director of American Studies.

Admission to honors in American Studies is by invitation of the committee in the student's junior year. The student must attain an average of 3.2 in major courses in addition to the university honors requirements.

# Anthropology

See listings under Social Relations.

# Applied Mathematics and Statistics

**Professors.** Edward F. Assmus, Jr., Ph.D. (Harvard); Bennett Eisenberg, Ph.D. (M.I.T.); B. K. Ghosh, Ph.D. (London); Samuel L. Gulden, M.A. (Princeton); Gregory T. McAllister, Ph.D. (Berkeley), *head;* George E. McCluskey, Ph.D. (Pennsylvania); Eric P. Salathe, Ph.D. (Brown); David A. Sanchez, Ph.D. (Michigan); Murray Schechter, Ph.D. (N.Y.U.); Gilbert A. Stengle, Ph.D. (Wisconsin).
**Associate professors.** Wei-Min Huang, Ph.D. (Rochester); Ramamirtham Venkataraman, Ph.D. (Brown).
**Assistant professors.** Penny Smith, Ph.D. (Poly. Inst. Brooklyn); Joseph E. Yukich, Ph.D. (M.I.T.).

The *Division of Applied Mathematics and Statistics* was established within the Department of Mathematics to promote and administer undergraduate and graduate education in applied mathematics and statistics, and to foster interdisciplinary research in the mathematical sciences at Lehigh. Courses and programs offered by the Division may be found under the departmental listing.

For a description of the graduate programs in Applied Mathematics, see the discussion under Interdisciplinary Graduate Programs on page 49 in Section IV.

# Apprentice Teaching

The apprentice teaching program is designed to benefit juniors and seniors who wish to learn about teaching under the guidance of an experienced teacher. Apprentices often do a limited amount of lecturing or leading of discussions, assist in making up and evaluating written assignments and are available for individual consultation with students.

To participate in the apprentice teaching program a student must:

1. Have an over-all cumulative grade point average of 2.80 or better;
2. Have a cumulative grade point average of at least 3.32 and have completed at least two courses in the major field in which apprentice teaching is done and;
3. Have previously taken for credit the course or its equivalent in which the apprentice teaching will be done.

A student may roster for apprentice teaching only once each semester, only once in a given course, and only twice during a college career.

To register for apprentice teaching each student-teacher partnership will submit a preliminary contract of duties and obligations for approval by the department chair and the dean of the student's college in which the course is taken. This form must be submitted before the first day of classes in the semester. To complete the course, the apprentice teachers will submit written reports of their experiences to the Office of the Provost.

**300. Apprentice Teaching (3)**
Supervised participation in various aspects of the teaching of a course. Transcript will identify department in which apprentice teaching was performed. Prerequisite: Consent of department chairperson.

# Art and Architecture

**Professors.** Tom F. Peters, M.Arch (ETH Zurich (dipl.Arch.ETH) and Dr.sc. (techn.) ETH Zurich, *director, Institute for the Study of High-Rise Habitat;* Richard J. Redd, M.F.A. (Iowa); Ricardo Viera, M.F.A. (R.I.S.D.), *director of Lehigh University Art Galleries.*
**Associate professors.** Nicholas Adams, Ph.D. (N.Y.U.); Lucy Gans, M.F.A. (Pratt), *chairwoman;* Ivan Zaknic, M.Arch. (Princeton).
**Assistant professors.** Drazen Cackovic, M.S. Arch. (Univ. of Cincinnati).
**Adjunct professors.** George Shortess, Ph.D. (Brown).
**Adjunct Assistant professors.** Pat Badt, M.F.A. (Univ. of Pennsylvania); Berrisford W. Boothe, M.F.A. (Maryland Institute College of Art); Daniel Brewer, M.F.A. (Tyler School of Art, Temple University).
**Adjunct lecturers.** Laurence Fink; Leslie J. Fletcher; Douglas Mason.

The department of art and architecture offers two major programs:

The architecture major is a multidisciplinary major based in the

department that draws on the resources of all Lehigh's colleges. Although architectural design is the primary concern of this major (beginning students should take Arch 1 and Arch 43) courses in architectural history, history, social sciences and engineering are recommended.

The architecture major leads to the liberal arts B.A. (bachelor of arts), a four-year degree. This degree is satisfactory for admission to graduate study in architecture and candidacy for the M.Arch. professional degree or for planning, preservation, or history of architecture.

In recent years students have gone on to graduate study in architecture at Yale, Harvard, Penn, Columbia and Washington University, among other schools, or to entry-level employment in the profession.

Double majors with Urban Studies are quite frequent and the Arts/Engineering five-year degree, in which the student earns both B.A. (architecture) and B.S. (civil engineering), is available. The Arts/Engineering program in architecture is under discussion at present. Participation for the class of 1993 is guaranteed but others should check with the chair in the department of art and architecture. For engineering students considering graduate study in architecture or an entry level position in an architectural-engineering firm an architecture minor is generally appropriate.

A major in art introduces the student to the basic media of art such as drawing, sculpture, printmaking, painting, and photography. For those interested in becoming a creative artist, intensive study at Lehigh as well as the other Lehigh Valley colleges is recommended; such a student can expect to take more than the required number of credits for the major.

A major in art can also be combined with psychology for those who seek a career in art therapy. It may also be combined with theater for those interested in costume design or with architecture and theater for those interested in set design. A major in art and minor in education is available for students interested in becoming public school art teachers.

A special track is available within the art major for students interested in art history.

The resources of the Lehigh University art collection are made available to many students taking classes in art. Prints, photographs, and paintings are often brought into the classroom and visits to art exhibitions on campus and elsewhere in the Lehigh Valley are a common part of art instruction.

Through the facilities of the Lehigh University art galleries, it is possible to see first-rate works of art on a regular basis. The annual contemporary art show is a special event. Several major museums are within easy traveling distance and the department runs regular bus trips to New York City. An annual lecture series has brought architects and artists to campus. In recent years Rodolfo Machado, Charles Gwathmey, Klaus Herdeg, Edmund Bacon, Steven Peterson, Thomas Armstrong, Rev. Howard Finster, Joyce Kozloff, Jonas Dos Santos, Geno Rodriguez, Harold Edgerton, Peter Berg, Jody Pinto have appeared at Lehigh. Cooperation with Moravian College allows students to register for art courses not offered at Lehigh, such as ceramics.

In addition to these two major programs, individually structured programs may be planned, such as art with an emphasis on architectural design, art history with an emphasis on museum training, and architecture with an emphasis on planning, urban studies, graphic communication, or government.

Minor programs may be established in architecture, art, graphic communication, and museum studies with a member of the department. Course requirements are specified, and a list of courses acceptable for the minors is available in the department.

## *Art Major*

Forty-two credit hours are required

**required preliminary courses** (21 credit hours)

| | |
|---|---|
| Art 5 | Introduction to the Visual Arts (3) |
| Art 7 | Basic Design (3) |
| Art 11 | Drawing I (3) |
| Art 13 | Sculpture I (3) |
| Art 20 | Color (3) |
| Art 121 | Drawing II (3) |
| Art 220 | 20th-Century Art (3) |

**plus one of the following:**

| | |
|---|---|
| Art 65 | Perception and the Visual Arts (3) |
| Art 82 | Art and Archaeology of Greece (3) |
| Art 111 | Women in Art (3) |
| Arch 210 | 20th-Century Architecture (3) |
| Art 219 | 19th-Century Painting (3) |

**six required major courses** (18 credit hours)
Art studio: six courses, two at the advanced level

Students interested in an art history concentration should substitute two preliminary studio courses with Art 1 and Art 2 or Arch 1. For the six required courses in art studio, courses in art history and museum studies should be substituted in consultation with an adviser. In order to complete an art history concentration students may be required to take courses in other LVAIC institutions.

## *Architecture Major*

Forty-nine credit hours are required.

**Design Sequence** (22 credit hours)

| | |
|---|---|
| Arch 043 | Architectural Design I (4) |
| Arch 143 | Architectural Design II (6) |
| Arch 243 | Architectural Design III (6) |
| Arch 343 | Architectural Design IV (6) |

**Art Studio** (9 credit hours)

| | |
|---|---|
| Art 11 | Drawing I (3) |

plus two other studios

**Architectural History** (9 credit hours)

| | |
|---|---|
| Arch 1 | Architectural History (3) |
| Arch 210 | 20th Century Architecture (3) |

plus one other course in architectural history (3)

**Architecture and its intellectual context** (9 credit hours)

| | |
|---|---|
| Arch 204 | Ancient City and Society (3) |
| Arch 207 | Renaissance Architecture (3) |
| Arch 209 | Architecture 1750-1880 (3) |
| Arch 213 | The City (3) |
| Arch 342 | Architectural Theory (3) |
| Art 201 | Archaeology: Lands of the Bible (3) |
| Anth 128 | Urban Ethnology (3) |
| Anth 335 | Religion, Symbolism and Cosmology (3) |
| Eco 311 | Environmental Economics (3) |
| Eco 312 | Urban Economics (3) |
| Hist 333 | American Urban History to 1880 (3) |
| Hist 334 | American Urban History, 1880 to Present (3) |
| Phil 123 | Aesthetics (3) |
| Psyc 373 | Sensation and Perception (3) |
| US 363 | Philadelphia: Development of a Metropolis (3) |

For the architecture major it is required that the mathematics requirement be filled with Math 21 & 22; the physical science requirement must be filled with Phys 11 & 12.

For students contemplating graduate studies in architecture, Mech 1 and Mech 11 are recommended.

## Undergraduate Courses in Art

**Art 1. Introduction to Art History I (3)** summer
Development of painting and sculpture primarily in the Western tradition from paleolithic to the Renaissance. Redd

**Art 2. Introduction to Art History II (3)** summer
Painting and sculpture primarily of Western civilization from the 16th Century to modern times. Redd

**Art 5. Introduction to the Visual Arts (3)** spring
Principles of visual expression. Examples of art from various periods are examined in relation of their historical and cultural context, to

their plastic organization and their significance as reflection of human experience. Redd

**Art 7. Basic Design** (3) fall
The exploration and organization of form as the fundamental component of design and drawing. Students are guided through projects in visual expression introducing them to principles utilizing line, shape, color, texture, value and mass in a variety of mediums.

**Art 11. Drawing I** (3) fall-spring
Concepts and practice of drawing, both traditional and contemporary. Includes drawing from life and an introduction to materials and techniques.

**Art 13. Sculpture I** (3)
Projects directed toward developing design in sculpture. Exploration of materials and their application. Emphasis on sculptural form as it relates to techniques. Gans

**Art 20. Color** (3) spring, alternate years
Projects directed toward building an awareness of color. Study and observation of the dynamics of color in theory and practice. Redd

**Art 23. Life Drawing I** (3)
Drawing from the live model as the fundamental experience leading toward an analysis of form in light and space. Emphasis on developing self-expression and on the methods and media of drawing.

**Art 37. Printmaking I** (3)
A structured course in mono print, wood cut, linocut and basic etching. Introducing materials and tools, stressing creative application and the conceptual aspects of the media. Prerequisite: Art 11. Redd

**Art 43. Graphic Communication I** (3) fall
Introduction to basic principles of visual communication that guide the development of creative solutions in graphic, printing, public relations, advertising design. Viera

**Art 65. (Psyc 65) Perception and the Visual Arts** (3)
Perceptual and cognitive theories and principles as related to visual fine arts and aesthetic experience. Shortess

**Art 77. Photography I** (3)
Introduction to photography as a fine art. Emphasis on interaction of technique, perception and communication in making and responding to photographic image. Lectures, demonstrations, critiques. Students must provide own hand camera. Prerequisite: consent of the chairperson.

**Art 82. (Clss 82) Art and Archaeology of Greece** (3)
The art and architecture of ancient Greece as revealed by archaeology. Brief surveys of the political and cultural backgrounds to the various artistic periods: Bronze Age, Geometric, Orientalizing, Classical, Hellenistic and Roman. Lectures, Slides and films.

**Art 111. Women in Art** (3)
Survey of works and lives of women artists from the Renaissance to the present; changing role of women in relation to the art establishment. Visits to museums and artists' studios. Gans

**Art 113. Sculpture II** (3)
Development of principles and techniques in Sculpture I. Modeling, casting, fabrication and carving. Emphasizes an approach to sculptural form and an exploration of the evolution of modern sculpture. Gans

**Art 121. Drawing II** (3)
Projects in creative drawing designed to build on concepts and practices initiated in basic drawing and life drawing. May be repeated for credit. Prerequisite: Art 11.

**Art 123. Life Drawing II** (3)
Advanced drawing from the live model. Prerequisite: Art 23. May be repeated for credit. Staff

**Art 135. Painting I** (3)
Painting in oil or acrylic oriented toward developing individual creative expression combined with an understanding of the physical nature of the materials. Studio prerequisite: Art 7, 11 or 20, or consent of department chairman. Staff

**Art 138. Printmaking II** (3)
Principles of Intaglio printing: drypoint and etching. Introduction to silk screen printing. Collagraph option. Prerequisite: Art 37. Redd

**Art 143. Graphic Communication II** (3) spring
Aspects of design are inter-related in function, concept or planning processes. Course emphasizes creativity and problems and solutions in visual communication. Workshops, team work, critiques, conferences. Prerequisite: Art 43 or consent of department chairman. Viera

**Art 177. Photography II** (3)
Intensive work in photography as fine art. Advanced study of problems of the photographic images. Lectures, demonstrations, critiques. Students must provide own hand camera. Prerequisite: Art 77.

**Art 179. History of Photography** (1)
Photography as fine art from earliest images to present day. Problems in contemporary photography.

**Art 201. (Clss 201) Archaeology: Lands of the Bible** (3)
Chronological survey of archaeological finds from Palaeolithic, Neolithic, Bronze Age, Iron Age, and later cultures in the Near East. Material illustrating the cultures and events of the Bible.

**Art 219. 19th-Century Painting** (3)
From Neoclassicism through the sequential movements of Romanticism, Naturalism, Impressionism, and Post-Impressionism in art of Europe and the United States. Redd

**Art 220. 20th-Century Art** (3)
The development of 20th-Century painting and sculpture from the foundations laid by Cezanne and Van Gogh through the revolutionary movements of cubism, expressionism, surrealism, abstract expressionism, and Pop. Illustrated lectures. Redd

**Art 222. Seminar in Contemporary Art** (3)
Recent aspects, developments in contemporary art. Exploring ideas and consequences of today's image-making. Studio workshops, readings, discussions and museum visits. Prerequisite: Art 2 or 5. Staff

**Art 231. Advanced Design** (3)
Directed projects and preparation of portfolio for advanced students in Studio Art and Graphic Communication. Prerequisite: Art 20, 113 or 143. Staff

**Art 235. Painting II** (3)
Problems in oil, watercolor, acrylic and mixed media. Prerequisite: Art 135.

**Art 237. Printmaking III** (3)
Directed project work which allows the student to pursue in greater depth specified printmaking processes in intaglio, relief, collagraph or silk screen. Working in larger scale. Greater technical demand. Prerequisite: Art 138. Redd

**Art 252. Advanced Studio Practice** (3)
Advanced studio for art or architecture majors under guidance of faculty. Oral and written critiques. Variable media. May be repeated for credit. Prerequisites: Art 7, 11, 37, 135 or consent of department chairman.

**Art 269. Special Topics in Art History** (3)
Directed projects for advanced students in the history of art or architecture. Prerequisite: consent of the department chairman. Staff

**Art 273. Special Topics in Studio Practice** (1-4)
Individually directed projects for advanced students capable of

undertaking independent creative work in studio art. Prerequisite: consent of the department chairman. Staff

**Art 277. Special Topics in Photography (1-4)**
Individually directed projects in photography for advanced student capable of undertaking creative work in photography. Prerequisites: Art 77, 177 and consent of department chairman.

**Art 321. Graphic Arts Internship (1-4)**
Practical in-field experience in graphic communication and graphic arts. Prerequisites: Art 143 and permission of chairman.

**Art 335. Painting III (3)**
Prerequisite: Art 235 or consent of the department chairman. May be repeated for credit. Staff

**Art 337. Printmaking Workshop (3)**
Independent experimentation and work in a chosen graphic media for the advanced student. Photographic applications, conceptual problems and mixed media. Conferences and critiques. May be repeated for credit. Prerequisite: Art 237 or consent of the department chairman. Redd

**Art 350. Special Topics (1-4)**
Independent study designed for graduate students in intermediate and advanced graphic communication for curriculum covered by Art 43, 143, 231.

## Undergraduate Courses in Architecture

**Arch 1. Architectural History (3)**
A survey of major monuments from the Pyramids to Post-Modernism. Works seen in context of development of design concepts, relation to structural change. Slide lectures. Field trips. Adams

**Arch 43. Architectural Design I (4)**
Fundamental design studio for potential architecture majors or minors. Two and three dimensional design with emphasis on form, space, function, color, and materials. An exploration of conceptualization, process, product, intention, and self-expression. Cackovic

**Arch 103. (Clss 103) Archaeology of Italy (3)**
Neolithic, Terramaran, Villanovan and Etruscan cultures. Rome the city: its buildings, monuments and streets, through the kingdom, republic, and empire. Survey of Pompeii, Herculaneum and Ostia. Lectures, readings and reports.

**Arch 143. Architectural Design II (6)**
Continuation of Arch 43. The design of small buildings with emphasis on drawing and modeling. An exploration of the evolution of architectural form and space, function, intention and meaning, as well as historical precedents and aesthetics. Previous or concurrent courses in studio art and architectural history, especially Arch 1 are strongly recommended. Prerequisite: Arch 43. Zaknic

**Arch 204. (Clss 204) Ancient City and Society (3)**
Ancient theories of city and city planning; attitudes to life in the city; rise of urban civilization from Neolithic prototypes through the Near East, Egypt, Greece, and Rome; insights applicable to current urban problems.

**Arch 206. The Gothic Cathedral (3)**
The architectural form and social context of medieval ecclesiastical architecture in Europe; emphasis on the cathedrals of Chartres, Paris, Amiens, and Reims. Adams

**Arch 207. Renaissance Architecture (3)**
History of architecture and urban form during the Italian Renaissance. Major architects (Brunelleschi to Palladio), building types (church, palace, and fortress), and urban centers (Pienza, Rome, and Venice). Adams

**Arch 209. Architecture 1750-1880 (3)**
From the industrial revolution to the skyscraper. The nature of industrial architecture and its effect on cities and city planning. Emphasis on France, England, Germany, and America. Adams

**Arch 210. 20th-Century Architecture (3)**
History and theory of architecture from 1880. Emphasis on Frank Lloyd Wright, Le Corbusier, and Mies Van der Rohe, and the problems of contemporary design. Adams, Zaknic

**Arch 213. The City (3)**
Historical development of urban design and the city. City planning as a response to topography, war and human needs. From ancient world to modern times. Adams, Zaknic

**Arch 243. Architectural Design III (6)**
Continuation of Arch 143. The design of larger, more complex buildings with an emphasis on contextural, environmental, sociological, psychological, and constructional concerns. Prerequisite: Arch 1, 43, 143, and one art studio. Cackovic

**Arch 271. Special Topics in Architecture (1-4)**
Directed projects for advanced students in architecture or architectural criticism. Prerequisites: Arch 1, 143, Art 11. Major standing in the department or consent of the department chairperson. Student must contact sponsoring professor and complete a contract sheet at preregistration.

**Arch 311. Portfolio (1)**
The concept, layout, and preparation of a portfolio for graduate school application or employment search, including graphic techniques and reproduction methods. Prerequisite: Art 121 or Art 335 or Arch 243. Staff

**Arch 321. Architectural Internship (1-3)**
Supervised internship in architectural firm, planning or preservation office. Internship plan must be approved in writing by chairman.

**Arch 342. Architectural Theory (3)**
Relations of architectural or urban history, theory, and practice. May be repeated for credit as topic varies. Cackovic

**Arch 343. Architectural Design IV (6)**
Continuation of Arch 243. The design of buildings and building groups, with the emphasis on urban design and the city. Prerequisite: Arch 1, 43, 143, 210, 243 and one art studio. May be repeated for credit. Staff

**Arch 345. Architectural Design V (3)**
Undergraduate thesis. An individual design project exploring, with faculty approval, some aspect of architecture of interest to the student. Prerequisite: Architectural Design I-IV; all other courses required for major, previously or concurrently.

**Arch 351. Computer Aided Design I (3)**
Use and role of computers in architecture. Computer aided design (CAD) system selection and operation, geometric modeling, design knowledge. Practical CAD work on a micro-CAD system through design and drafting of architectural projects. Prerequisite: Arch 143 or consent of chairman.

**Arch 352. Computer Aided Design II (3)**
Use of computer aided design as a tool to design and draft in the area of art, architecture, urban design and structures. Provides an advanced hands on experience both in the early and the detailed stages of design using a micro-CAD system. Prerequisite: Arch 351 or consent of chairman.

**Arch 388. Advanced Architectural Design (3)**
Intensive design projects under a sequence of visiting design instructors. Prerequisites: Arch 210, 243 and consent of the department chairman. Zaknic

## Museum Studies

**Art 175. Introduction to Museum Work (3) fall-spring**
Introduction to the methods and procedures of research on art objects, historical sites, and documents. The nature of museum work in its

practical aspects. Field trips and workshops. Each student completes a research report or equivalent. Prerequisite: consent of the department chairman. Viera

**Art 275. Museography and Museology (1-3)** fall-spring
Theory and practice in contemporary museums and galleries. Research in the Lehigh University art collection. Curatorial problems in interpretation, display, cataloging and conservation. Each student completes a research report or equivalent. May be repeated for credit. Viera

**Art 375. Internship (3)** fall-spring
Internship under professional supervision in the principal museum areas: curatorship, conservation, exhibition, interpretation, and administration in association with the Lehigh University Art Galleries, Historic Bethlehem, Inc. and Lehigh County Historical Society. Prerequisite: Art 175, 275 and consent of the department chairman. May be repeated for credit. Viera

# Arts and Science

**1. Choices and Decisions (1)**
Introduction to decision making with emphasis on curriculum, career planning, and social options. Techniques for using values, family history, and social norms as guidelines for decision making processes. Pass-fail grading.

**11. Sex Roles and Society: Continuity and Change (3)**
Interdisciplinary study of sex roles — their existing character and impact upon individuals and institutions: masculine and feminine social roles in fiction; historical attitudes toward marriage and men's and women's work; research on sex differences; ideals of sex equality.

**111. The American Character (3)**
A chronological and methodological analysis of the shifting conceptions of 'this new man, the American.' Readings are selected from foreign and domestic observers ranging from Crevoeur to Christopher Lasch. Special attention is given to the conceptual difficulties of analyzing national character and to the debate over such an analysis. Dowling

# Arts-Engineering

G. Mark Ellis, Ph.D., associate dean, College of Arts and Science, *curriculum director.*

The standard major for arts-engineers working towards a bachelor of science degree is applied science. This includes all of the science and engineering courses required in the freshman year and included in the pattern roster for the chosen field of engineering.

Arts-engineers with special interests outside engineering frequently combine another arts or science major with their engineering program. Interested students should consult with the curriculum director.

**Recommended freshman year.** Arts-engineering freshmen have the same roster of courses as do engineering freshmen, with the exception that the arts-engineering freshman takes Eco 1 in the second semester in place of an elective. Refer to the recommended freshman year, page 37.

**Recommended professional sequences.** Beginning with the sophomore year, the arts-engineering student will be guided by the appropriate pattern roster in the chosen field. The pattern roster shows the most effective way of combining arts and engineering courses to prepare for the last year in the branch of engineering chosen.

Although the minimum number of credit hours needed for the bachelor of arts degree is 121, a student in arts-engineering should expect to earn more than this in order to qualify for the bachelor of science degree in the chosen field of engineering at the end of the fifth year. The number of credits needed for both degrees is shown for each pattern roster.

## Arts-Chemical Engineering

A total of 165 credit hours are needed for the bachelor of arts and the bachelor of science degree.

For the freshman year, see page 37. See electives (b) through (f) for the chemical engineering program on page 90-91. Careful planning is required so that these may be scheduled during the senior year and fifth year of the program. Any order that does not violate prerequisistes is acceptable.

**sophomore year, first semester** (17 credit hours)

| | |
|---|---|
| Math 23 | Analytic Geometry and Calculus III (4) |
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) |
| ChE 43 | Introduction to Chemical Engineering (4) |
| | distribution electives (6) |

**sophomore year, second semester** (16 credit hours)

| | |
|---|---|
| Math 205 | Linear Methods (3) |
| ChE 44 | Chemical Process Analysis I (4) |
| Chem 187 | Physical Chemistry I (3) |
| | distribution electives (6) |

**junior year, first semester** (17 credit hours)

| | |
|---|---|
| Chem 51 | Organic Chemistry (3) |
| Chem 53 | Organic Chemistry Laboratory (1) |
| ChE 141 | Chemical Process Analysis II (4) |
| | distribution electives (9) |

**junior year, second semester** (18 credit hours)

| | |
|---|---|
| Chem 52 | Organic Chemistry (3) |
| ChE 142 | Chemical Process Analysis III (4) |
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |
| | distribution electives (6) |

**senior year, first semester** (17 credit hours)

| | |
|---|---|
| Chem 189 | Physical Chemistry II (3) |
| Chem 192 | Physical Chemistry Laboratory (2) |
| | electives for engineering major (6)* |
| | distribution electives (6) |

**senior year, second semester** (16 credit hours)

| | |
|---|---|
| ChE 202 | Chemical Engineering Laboratory I (3) |
| ChE 210 | Chemical Engineering Thermodynamics (4) |
| | elective for engineering major (6)* |
| | distribution elective (3) |

**fifth year**

See program description for senior year of chemical engineering, page 90.

*These electives are chosen with the chemical engineering adviser.

## Arts-Civil Engineering

A total of 162 credit hours are needed for the bachelor of arts and the bachelor of science degrees.

**freshman year** (see page 37)

**sophomore year, first semester** (16 credit hours)

| | |
|---|---|
| Math 23 | Analytic Geometry and Calculus III (4) |
| Mech 1 | Statics (3) |
| Geol 161 | Geology for Engineers (3) |
| | distribution electives (6) |

**sophomore year, second semester** (18 credit hours)

| | |
|---|---|
| Math 205 | Linear Methods (3) |

| | |
|---|---|
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |
| CE 112 | Surveying (4) |
| | distribution electives (6) |

**junior year, first semester** (18 credit hours)

| | |
|---|---|
| Mech 11 | Mechanics of Materials (3) |
| Mat 92 | Structure and Properties of Materials (3) |
| CE 15 | Graphics for Civil Engineering (3) |
| | distribution electives (9) |

**junior year, second semester** (18 credit hours)

| | |
|---|---|
| Mech 102 | Dynamics (3) |
| CE 117 | Numerical Methods in Civil Engineering (2) |
| Eco 1 | Economics (4) |
| | distribution electives (9) |

**senior year, first semester** (17 credit hours)

| | |
|---|---|
| CE 121 | Mechanics of Fluids (3) |
| CE 143 | Soil Mechanics (4) |
| CE 159 | Structural Analysis I (4) |
| | distribution electives (6) |

**senior year, second semester** (17 credit hours)

| | |
|---|---|
| CE 160 | Structural Design (4) |
| CE 202 | Civil Engineering Planning and Engineering Economics (3) |
| CE 222 | Hydraulic Engineering (4) |
| | distribution electives (6) |

**fifth year, first semester** (18 credit hours)

| | |
|---|---|
| CE 207 | Transportation Engineering (3) |
| CE 215 | Probability and Statistics in Civil Engineering (3) |
| | Civil Engineering electives (6) |
| | distribution electives (6) |

**summer**

| | |
|---|---|
| CE 100 | Summer Employment (0) |

Eight weeks of summer employment should precede the fifth year.

**fifth year**

See program description for senior year of civil engineering, page 105.

A total of 168 credit hours are required for the BA and the BS degrees.

## Arts-Computer Engineering

A total of 159 credit hours are needed for the bachelor of arts and the bachelor of science degrees. For the freshman year, see page 37.

**sophomore year, first semester** (16 credit hours)

| | |
|---|---|
| Math 23 | Analytic Geometry and Calculus III (4) |
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |
| CSc 33 | Principles of Computer Engineering (4) |
| | distribution elective (3) |

**sophomore year, second semester** (16 credit hours)

| | |
|---|---|
| CSc 17 | Structured Programming and Data Structures (4) |
| CSc 261 | Discrete Structures (3) |
| Math 205 | Linear Methods (3) |
| | distribution electives (6) |

**junior year, first semester** (16 credit hours)

| | |
|---|---|
| ECE 81 | Principles of Electrical Engineering (4) |
| Math 231 | Probability and Statistics (3) **or** |
| Math 309 | Theory of Probability (3) |
| | distribution electives (9) |

**junior year, second semester** (16 credit hours)

| | |
|---|---|
| ECE 116 | Software Engineering (3) |
| ECE 108 | Signals and Systems (4) |
| | distribution electives (9) |

**senior year, first semester** (14 credit hours)

| | |
|---|---|
| ECE 121 | Electronic Circuits Laboratory (2) |
| ECE 123 | Electronic Circuits (3) |
| ECE 125 | Circuits and Systems (3) |
| | elective (3) |
| | distribution electives (3) |

**senior year, second semester** (14 credit hours)

| | |
|---|---|
| ECE 138 | Digital Systems Laboratory (2) |
| ECE 201 | Computer Architecture (3) |
| | approved elective* (3) |
| | distribution electives (6) |

**fifth year**

See program description for senior year of computer engineering, page 116.

*These electives require approval of the department of computer science and electrical engineering. They are subjects in the area of science and technology, not restricted to offerings of the department.

## Arts-Electrical Engineering

A total of 158 credit hours are needed for the bachelor of arts and bachelor of science degrees. For the freshman year, see page 37.

**sophomore year, first semester** (15 credit hours)

| | |
|---|---|
| Math 23 | Analytic Geometry and Calculus III (4) |
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |
| | distribution electives (6) |

**sophomore year, second semester** (15 credit hours)

| | |
|---|---|
| Math 205 | Linear Methods (3) |
| | technical elective (3) |
| | distribution electives (9) |

**junior year, first semester**(17 credit hours)

| | |
|---|---|
| ECE 81 | Principles of Electrical Engineering (4) |
| CSc 33 | Principles of Computer Engineering (4) |
| Math 231 | Probability and Statistics (3) **or** |
| Math 309 | Theory of Probability (3) |
| | distribution electives (6) |

**junior year, second semester** (16 credit hours)

| | |
|---|---|
| ECE 108 | Signals and Systems (4) |
| | approved elective* (3) |
| | distribution electives (9) |

**senior year, first semester** (14 credit hours)

| | |
|---|---|
| ECE 121 | Electronic Circuits Laboratory (2) |
| ECE 123 | Electronic Circuits (3) |
| ECE 125 | Circuits and Systems (3) |
| | approved elective* (3) |
| | distribution electives (3) |

**senior year, second semester** (17 credit hours)

| | |
|---|---|
| ECE 126 | Physical Electronics (3) |
| ECE 136 | Electromechanics (3) |
| ECE 138 | Digital Systems Laboratory (2) |
| ECE 202 | Introduction to Electromagnetics (3) |
| | approved elective* (3) |
| | distribution elective (3) |

**fifth year**

See program description for senior year of electrical engineering, page 115-116.

*These electives require approval of the department of computer science and electrical engineering. Approved electives are subjects predominantly in the area of science and technology. They are not restricted to offerings in the department. Students must choose at least one elective in mathematics, at least one elective in either materials, thermodynamics, fluid mechanics, or physical chemistry, and at least one elective in physics, chemistry, or biology.

## Arts-Engineering Physics

A total of 161 credit hours are needed for the bachelor of arts and bachelor of science degrees. For the freshman year, see page 37.

**sophomore year, first semester** (15 credit hours)
Phys 21 Introductory Physics II (4)
Phys 22 Introductory Physics Laboratory II (1)
Math 23 Analytic Geometry and Calculus III (4)
distribution electives (6)

**sophomore year, second semester** (15 credit hours)
Phys 31 Introduction to Quantum Mechanics (3)
Math 205 Linear Methods (3)
distribution electives (9)

**junior year, first semester** (15 credit hours)
Phys 212 Electricity and Magnetism I (3)
Phys 215 Classical Mechanics I (3)
Math 322 Methods of Applied Analysis I (3)
distribution electives (3)
electives (3)*

**junior year, second semester** (18 credit hours)
Phys 213 Electricity and Magnetism II (3)
Phys 190 Electronics (3)
Phys 362 Atomic and Molecular Structure (3)
distribution electives (6)
electives (3)*

**senior year, first semester** (17 credit hours)
Phys 260 Laboratory Techniques (2)
Phys 216 Classical Mechanics II (3)
distribution electives (6)
electives (3)*

**senior year, second semester** (17 credit hours)
Phys 261 Optics, Spectroscopy, and Quantum Physics Laboratory (2)
Phys 264 Nuclear and Elementary Particle Physics (3)
distribution electives (6)
electives (6)*

**fifth year, first semester** (18 credit hours)
Phys 340 Thermal Physics (3)
electives (15)

**fifth year, second semester** (15 credit hours)
Phys 171 Physics Proseminar (1)
electives (14)

*The electives include at least fourteen credit hours of approved technical electives, including two of the courses Phys 363, 369, (352 or 355), and (346 or 348 or 365). Students planning graduate work in physics are advised to include Phys 273 and 369 among their electives.

## Arts-Industrial Engineering

A total of 159 credit hours are needed for the bachelor of arts and bachelor of science degrees. For the freshman year, see page 37.

**sophomore year, first semester** (16 credit hours)
Math 23 Analytic Geometry and Calculus III (4)
Phys 21 Introductory Physics II (4)
Phys 22 Introductory Physics Laboratory II (1)
IE 111 Engineering Probability and Statistics (3)
IE 112 Computer Graphics (1)
distribution elective (3)

**sophomore year, second semester** (16 credit hours)
IE 121 Applied Engineering Statistics (3)
IE 122 Software Tools (1)
IE 124 Engineering Economy and Decision Analysis (3)
distribution electives (9)

**junior year, first semester** (15 credit hours)
Math 205 Linear Methods (3)
IE 221 Operations Research - Probabilistic Models (3)
Mat 63 Engineering Materials and Processes (3)
distribution electives (6)

**junior year, second semester** (16 credit hours)
IE 222 Operations Research - Deterministic Models (3)
ECE 81 Principles of Electrical Engineering (4)
distribution electives (9)

**senior year, first semester** (16 credit hours)
IE 115 Fundamentals of Modern Manufacturing (3)
IE 116 Manufacturing Laboratory (1)
engineering science elective (3)*
distribution electives (9)

**senior year, second semester** (16 credit hours)
IE 131 Work Systems and Facilities Planning (3)
IE 132 Work Systems and Facilities Planning Laboratory (1)
engineering science electives (6)*
electives (3)
distribution elective (3)

**summer**
IE 100 Industrial Employment (0)

**fifth year**

See program description for senior year of Industrial Engineering, page 00.

*Note: Engineering science electives must be approved by the department of industrial engineering adviser.

## Arts-Mechanical Engineering and Mechanics

A total of 161 credit hours are needed for the bachelor of arts and the bachelor of science degrees. For the freshman year, see page 46.

**sophomore year, first semester** (16 credit hours)
Phys 21 Introductory Physics II (4)
Phys 22 Introductory Physics Laboratory II (1)
Math 23 Analytic Geometry and Calculus III (4)
ME 10 Graphics for Engineering Design (4)
distribution electives (3)

**sophomore year, second semester** (18 credit hours)
Mech 1 Statics (3)
Math 205 Linear Methods (3)
distribution electives (12)

**junior year, first semester** (15 credit hours)
ME 104 Thermodynamics I (3)
Mech 11 Mechanics of Materials (3)
distribution electives (9)

**junior year, second semester** (15 credit hours)
Mech 102 Dynamics (3)
ME 21 Mechanical Engineering Laboratory I (1)
ME 231 Fluid Mechanics (3)
ECE 81 Principles of Electrical Engineering (4)

| | |
|---|---|
| ECE 162 | Electrical Laboratory (1) |
| ME 105 | Thermodynamics II (3) |

**senior year, first semester** (15 credit hours)

| | |
|---|---|
| Mat 63 | Engineering Materials and Processes (3) |
| Math 208 | Complex Variables (3) **or** |
| Math 231 | Probability and Statistics (3) |
| Mech 203 | Advanced Strength of Materials (3) |
| | distribution electives (6) |

**senior year, second semester** (18 credit hours)

| | |
|---|---|
| ME 101 | Mechanical Engineering Design I (2) |
| ME 151 | Mechanical Elements (3) |
| ME 242 | Mechanical Vibrations (3) |
| ME 121 | Mechanical Engineering Laboratory II (1) |
| | distribution electives (6) |
| | elective (3) |

**fifth year**

See program description for senior year of mechanical engineering & mechanics, page 187.

### Arts-Materials Science and Engineering

A total of 164 to 166 credit hours are needed for the bachelor of arts and bachelor of science degrees, depending on the option selected. For the freshman year, see page 37.

**sophomore year, first semester** (16 credit hours)

| | |
|---|---|
| Mat 63 | Engineering Materials and Processes (3) **or** |
| Mat 93 | Introduction to Solid State Materials (3) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |
| Mat 10 | Materials Laboratory (1) |
| | distribution elective (3) |

**sophomore year, second semester** (15 credit hours)

| | |
|---|---|
| Mech 1 | Statics (3) |
| Math 205 | Linear Methods (3) **or** |
| Math 231 | Probability and Statistics (3) |
| | distribution electives (9) |

**junior year, first semester** (15 credit hours)

| | |
|---|---|
| Chem 207 | Metallic Elements (3) |
| Mat 207 | Crystal Structure and Atom Movements (3) |
| Mat 210 | Metallurgical Thermodynamics (3) |
| Mech 11 | Mechanics of Materials (3) |
| | distribution electives (3) |

**junior year, second semester** (15-16 credit hours)

| | |
|---|---|
| Mat 208 | Phase Diagrams and Transformations (3) |
| Mat 218 | Mechanical Behavior of Materials (3) |
| ECE 81 | Principles of Electrical Engineering (4) **or** |
| Phys 31 | Introduction to Quantum Mechanics (3) |
| | distribution electives (6) |

**senior year, first semester** (15 credit hours)

| | |
|---|---|
| Mat 307 | Materials Engineering I (3) |
| ChE 60 | Unit Operations Survey (3) |
| | distribution electives (9) |

**senior year, second semester** (18 credit hours)

| | |
|---|---|
| Mat 101 | Professional Development (2) |
| Mat 212 | Electronic Behavior of Solids (3) |
| Mat 304 | Chemical Metallurgy (4) |
| | distribution electives (6) |
| | elective (3) |

**summer**

| | |
|---|---|
| Mat 100 | Industrial Employment |

**fifth year**

See program description for senior year of materials science and engineering, page 176.

Note: Students interested in the industrial or research options should consult with the department chairperson prior to their fourth year. Students selecting the research option should elect Mat 240, Research Techniques, in the second semester of the senior year.

# Arts-Master of Business Administration Program

The arts-master of business administration two-degree program is a special opportunity offered by the College of Arts and Science. See Section III for a description.

# Asian Studies

The East Asian Studies minor program is an opportunity in the College of Arts and Science. A description of the program is found in Section III.

# Astronomy

**Professor.** George E. McCluskey, Ph.D. (Pennsylvania), *head.*

Astronomy is offered in the department of mathematics.

**1. The Solar System (3)** fall
Survey of our knowledge of the solar system. Apollo lunar missions. Mariner missions to Mercury, Venus and Mars. Viking missions to Mars. Missions to Jupiter and Saturn.

**2. Stellar Astronomy (3)** spring
Survey of our knowledge of stars and stellar systems. Observation and theory of pulsars, quasars, X-ray sources, gamma-ray sources, neutron stars and black holes.

**171. Readings (1-3)** fall-spring
For nonscience majors to study an area of astronomy more deeply than at the introductory level. Individual supervision. Prerequisites: Astr 1 or Astr 2, and Math 21 or Math 31 or Math 41. May be repeated for credit with the consent of the division head.

**211. Stellar Structure and Evolution (3)** fall, even-numbered years
Physical processes in stellar interiors. Theory of stellar evolution and interpretation of observations. Binary star evolution. Theory of novae and supernovae. Prerequisites: Math 23 or Math 32 or Math 44, previously or concurrently, and Phys 21.

**221. Stellar Atmospheres (3)** fall, odd-numbered years
Observation and theory of stellar spectra. Model atmospheres and chemical abundances. Extended atmospheres, stellar winds and mass loss. Theory of gaseous nebulae. Prerequisites: Math 23 or Math 32 or Math 44, previously or concurrently, and Phys 21.

**232. High-Energy Astrophysics (3)** spring, odd-numbered years
Observation and theory of X-ray and gamma-ray sources, quasars, pulsars, radio galaxies, neutron stars, black holes. Results from ultraviolet, X-ray and gamma ray satellites. Prerequisites: Math 23 or Math 32 or Math 44, previously or concurrently, and Phys 21.

**242. Relativity and Cosmology (3)** spring, even-numbered years
Special and general relativity. Schwarzschild and Kerr black holes. Supermassive stars. Relativistic theories of the origin and evolution of the universe. Prerequisites: Math 23 or Math 32 or Math 44, previously or concurrently, and Phys 21.

**350. Topics in Astrophysics (3)** fall-spring
For science or engineering majors who desire to study an active area of research in astrophysics. Individual supervision. Prerequisites: Astr 2, and Math 23 or Math 32. May be repeated for credit with the consent of the division head.

# Biology

**Professors.** Jeffrey A. Sands, Ph.D. (Penn State), *chairperson;* John H. Abel, Ph.D. (Brown); Sidney S. Herman, Ph.D. (Rhode Island); Steven Krawiec, Ph.D. (Yale).
**Associate professors.** Barry Bean, Ph.D. (Rockefeller); David Cundall, Ph.D. (Arkansas); Bruce R. Hargreaves, Ph.D. (Berkeley); Murray Itzkowitz, Ph.D. (Maryland); Hayden N. Pritchard, Ph.D. (Lehigh); Craig E. Williamson, Ph.D. (Dartmouth).
**Assistant professors.** Michael R. Kuchka, Ph.D. (Carnegie-Mellon); Paul B. Samollow, Ph.D. (Oregon State); Vassie C. Ware, Ph.D. (Yale).
**Joint faculty.** Arthur E. Humphrey, Ph.D. (Columbia); Janice A. Phillips, Ph.D. (Pennsylvania).

Biology includes the study of living systems at levels ranging from the molecular structure of specific genes to the complex interactions among organisms.

The Department of Biology offers three major programs: the Bachelor of Arts in Biology; the Bachelor of Science in Biology; and the Bachelor of Science in Molecular Biology. The B.A. program requires 28 hours of Biology courses as compared to 34 hours in each of the B.S. programs. The B.A. program requires completion of the College of Arts and Science distribution requirements, whereas the B.S. programs require completion of 30-34 hours of non-science courses including experience in both the humanities and social sciences.

In addition to the biology and molecular biology programs, the Department of Biology and the Department of Psychology jointly administer B.A. and B.S. programs in Behavioral and Neural Biology.

All of the B.S. programs are designed for pre-professional education, and include requirements commonly expected for post-graduate degree programs in the sciences. The B.A. programs offer greater flexibility for the student to elect courses of interest in a variety of disciplines. Both B.S. and B.A. candidates should consult their academic advisers for course choices most appropriate to their post-graduate plans.

Note: The biology curricula are in the process of being revised, with the expectation that revisions to be approved in Fall 1989 will provide a new basic set of core courses, replacing Biol 21, 22, and 28, for the B.A. and B.S. programs.

## *B.A. with Major in Biology*

**College and university requirements**

| | |
|---|---|
| Engl 1 | Composition and Literature (3) |
| Engl 2, 4, 6, 8 or 10 | Composition and Literature: Fiction, Drama, Poetry (3) |
| A&S 1 | Choices and Decisions (1) |

Distribution Requirements (see page 28)

**Major Program** (45 credit hours)

*Biology* (28 credit hours)

| | |
|---|---|
| Biol 21 | Principles of Biology (3)* |
| Biol 22 | Introduction to Biology Laboratory (1)* |
| | Biol approved electives (24 credit hours) |

(See "Note" above)

*Mathematics* (6 credit hours)

| | |
|---|---|
| Math 41 | BMSS Calculus I (3)* |
| Math 44 | BMSS Calculus II (3)* |

*Chemistry/Physics* (11 credit hours)

| | |
|---|---|
| Chem 21 | Introductory Chemical Principles (4)* |
| Chem 22 | Chemical Principles Laboratory (1)* |
| Chem 51 | Organic Chemistry (3) |

and one of the following:

| | |
|---|---|
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) **or** |
| Chem 194 | Physical Chemistry for Biological Sciences (3) **or** |
| Phys 11 | Introductory Physics I (4) |

*Although no specific sequence is required, it is recommended that courses marked with an asterisk be completed during the freshman year.

## The B.S. in Biology

The bachelor of science in biology offers broad scientific preparation in biology to facilitate entry into the life sciences. Progression through the program is best served through early commitment.

## *Requirements for the B.S. in Biology*

**College and university requirements** (37 credit hours)

| | |
|---|---|
| Engl 1 | Composition and Literature (3) |
| Engl 2, 4, 6, 8 or 10 | Composition and Literature: Fiction, Drama, Poetry (3) |
| A&S 1 | Choices and Decisions (1) |
| Non-science electives | (30), to be broadly distributed in fields of thought other than natural sciences and mathematics, including at least 12 credit hours each in the humanities and social sciences. |

**Major Program** (34 or 35 credit hours)

*Biology*

| | |
|---|---|
| Biol 21 | Principles of Biology (3) |
| Biol 22 | Introduction to Biology Laboratory (1) |
| Biol 28 | Mendelian and Population Genetics (3) |

(See Note on revisions)

| | |
|---|---|
| Biol 131 | Non-Vascular Plants (3) **or** |
| Biol 132 | Evolution of Vascular Plants (3) |
| Biol 133 | Invertebrate Zoology (3) **or** |
| Biol 134 | Comparative Vertebrate Anatomy (4) |
| Biol 211 | Ecology (3) |
| Biol 220 | Cell Physiology (3) **or** |
| Biol 223 | Animal Physiology (3) |
| Biol 235 | Microbiology (3) |
| Biol 317 | Evolution (3) |
| | Biol electives (9) |

*Mathematics* (12 credit hours)
either

| | |
|---|---|
| Math 21, 22, 23 | Analytic Geometry and Calculus I, II and III (12) |

or

| | |
|---|---|
| Math 41, 44, 42, 43 | BMSS Calculus I, II, Probability and Linear Algebra (12) |

*Collateral Sciences*

| | |
|---|---|
| Chem 21 | Introductory Chemical Principles (4) |
| Chem 22 | Chemical Principles Laboratory (1) |
| Chem 51, 52 | Organic Chemistry I and II (6) |

| | |
|---|---|
| Chem 53, 58 | Organic Chemistry Laboratory I and II (2) |
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) |
| Chem 187 or 194 | Physical Chemistry I (3) |
| Phys 11 | Introductory Physics I (4) |
| Phys 12 | Introductory Physics Laboratory I (1) |
| Phys 13 | General Physics (3) |
| Phys 14 | General Physics Laboratory (1) |
| Geol 21 | Principles of Geology (3) |
| elective | any course in the natural sciences or mathematics (3) |

and one of the following:

| | |
|---|---|
| Psyc 1 | Introduction to Psychology (3) |
| Psyc 110 | Experimental Design and Statistical Analysis (3) |
| Phil 128 | Philosophy of Science (3) |

## *Recommended B.S. Science Sequence*

**freshman year**

| | |
|---|---|
| Biol 21, 22 | Principles of Biology and Laboratory (4) |
| Biol 28 | Mendelian and Population Genetics (3) |
| Math 21, 22 | Analytic Geometry and Calculus I and II (8) **or** |
| Math 41, 44 | BMSS Calculus I and II (6) |
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |

**sophomore year**

| | |
|---|---|
| Chem 51, 52, 53, 58 | Organic Chemistry and Laboratory (8) |
| Math 23 | Analytic Geometry and Calculus III (4) **or** |
| Math 42, 43 | BMSS Probability and Linear Algebra (6) |
| Biol 131 | Non-Vascular Plants (3) **or** |
| Biol 132 | Evolution of Vascular Plants (3) |
| Biol 133 | Invertebrate Zoology (3) **or** |
| Biol 134 | Comparative Vertebrate Anatomy (4) |
| elective | Psych 1, Introduction to Psychology (3) or Psych 110, Psychological Research and Statistics (3) or Phil 128, Philosophy of Sciences (3) |

**junior year**

| | |
|---|---|
| Geol 21 | Principles of Geology (3) |
| Phys 11, 12 | Introductory Physics I and Laboratory (5) |
| Phys 13, 14 | General Physics and Laboratory (4) |
| Biol 235 | Microbiology (3) |
| Biol 211 | Ecology (3) |
| Biol 220 | Cell Physiology (3) **or** |
| Biol 223 | Animal Physiology (3) |
| | elective (3) |

**senior year**

| | |
|---|---|
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) |
| Chem 187 or 194 | Physical Chemistry I (3) |
| Biol 317 | Evolution (3) |
| | Biol electives (6) |
| elective | natural sciences (3) |

# The B.S. in Molecular Biology

The B.S. program in molecular biology enables students to focus on this distinctive and highly interdisciplinary field. The nature of the field requires extensive course work in chemistry, physics, mathematics and biology, and specialized laboratory and research experience. The molecular biology curriculum requires highly structured scheduling through three years of the program.

## *Requirements for the B.S. in Molecular Biology*

**College and university requirements** (37 credit hours)

| | |
|---|---|
| Engl 1 | Composition and Literature (3) |
| Engl 2, 4, 6, 8 or 10 | Composition and Literature: Fiction, Drama, Poetry (3) |
| A&S 1 | Choices and Decisions (1) |
| Non-science electives | (30), to be broadly distributed in fields of thought other than natural sciences and mathematics, including at least 12 credit hours each in the humanities and social sciences. |

**Major Program**

*Mathematics* (12 credit hours)

| | |
|---|---|
| Math 21, 22, 23 | Analytic Geometry and Calculus I, II and III (12) |

*Chemistry* (19 credit hours)

| | |
|---|---|
| Chem 21 | Introductory Chemical principles (4) |
| Chem 22 | Chemical Principles Laboratory (1) |
| Chem 51, 52 | Organic Chemistry (6) |
| Chem 53, 58 | Organic Chemistry Laboratory (2) |
| Chem 31, 194 | Chemical Equilibria in Aqueous Systems and Physical Chemistry for Biological Sciences (6) |

*Physics* (9 credit hours)

| | |
|---|---|
| Phys 11 | Introductory Physics I (4) |
| Phys 12 | Introductory Physics Laboratory I (1) |
| Phys 13 | General Physics (3) |
| Phys 14 | General Physics Laboratory (1) |

*Natural sciences, mathematics or computing science* (6 credit hours)

| | |
|---|---|
| electives | (6) |

*Molecular Biology* (33 credit hours)

| | |
|---|---|
| Biol 21 | Principles of Biology (3)* |
| Biol 28 | Mendelian and Population Genetics (3)* |
| (See note on revisions) | |
| Biol 220 | Cell Physiology (3) |
| Biol 235 | Microbiology (3) |
| Chem 371 | Elements of Biochemistry I (3) |
| Chem 372 | Elements of Biochemistry II (3) |
| Biol 367 | Molecular and Cellular Biophysics (3) |
| Biol 345 | Molecular Genetics (3) |

and 9 credit hours, including at least one course with laboratory † from the following:

| | |
|---|---|
| Biol 391 | Undergraduate Research (3) † |
| Biol 325 | Topics in Genetics (3) |
| Biol 327 | Cellular Regulation (3) † |
| Biol 353 | Virology (3) |
| Chem 377 | Biochemistry Laboratory (3) † |
| Chem 378 | Biochemical Preparations (1-3) † |
| ChE 341 | Biotechnology I (3) |
| ChE 342 | Biotechnology II (3) |

† designates laboratory courses within this category.

## *Recommended sequence for the B.S. in Molecular Biology*

**freshman year**

| | |
|---|---|
| Biol 21 | Principles of Biology (3) |
| Biol 28 | Mendelian and Population Genetics (3) |
| Math 21, 22 | Analytic Geometry and Calculus I and II (8) |
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |
| Phys 11, 12 | Introductory Physics I and Laboratory (5) |

**sophomore year**

| | |
|---|---|
| Biol 220 | Cell Physiology (3) |
| Biol 235 | Microbiology (3) |

| | |
|---|---|
| Math 23 | Analytic Geometry and Calculus III (4) |
| Chem 51, 52 | Organic Chemistry (6) |
| Chem 53, 58 | Organic Chemistry Laboratory (2) |
| Phys 13, 14 | General Physics and Laboratory (4) |
| **junior year** | |
| | Biol elective (3) |
| Biol 345 | Molecular Genetics (3) |
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) |
| Chem 194 | Physical Chemistry for Biological Sciences (3) |
| Chem 371, 372 | Elements of Biochemistry I and II (6) |
| **senior year** | |
| | electives (6) |
| Biol 367 | Molecular and Cellular Biophysics (3) |
| | Natural science electives (6) |

## *Major Program in Behavioral and Neural Biology (BNB)*

Co-sponsored by the departments of psychology and biology and offering both B.A. and B.S. degrees, this major examines the physiology, genetics and evolution of behavior. An interdisciplinary program, BNB draws upon psychology, biology, chemistry and anthropology with an emphasis on the neurosciences. Additional math and science courses are necessary to round out these curricula.

## *B.A. in Behavioral and Neural Biology*

The B.A. in Behavioral and Neural Biology is a natural science major for B.A. distribution purposes.

## *Required Major Courses*

**Core Courses**

| | |
|---|---|
| Psyc 1 | Introduction to Psychology (3) **or** |
| Psyc 11 | Introduction to Psychology: Discussion Format (3) |
| Biol 21 | Principles of Biology (3)* **and** |
| Biol 22 | Introduction to Biology Laboratory (1)* |
| (See note on revisions) | |
| Anth 12 | Emergence of Mankind and Culture (3) |
| Biol 28 | Mendelian and Population Genetics (3) |
| Psyc 110 | Experimental Design and Statistical Analysis (3) |
| Psyc 210 | Experimental Psychology (4) |
| Psyc 177 | Introduction to Physiological Psychology (3) |

**Category 1: take one course**

| | |
|---|---|
| Biol/Psyc 335 | Animal Behavior (3) |
| Biol/Psyc 337 | Sociobiology (3) |

**Category 2: take one course**

| | |
|---|---|
| Psyc/Biol 375 | Neuroanatomy of Behavior (3) |
| Psyc 283/Biol 376 | Endocrinology of Behavior (3) |

**Category 3: nine credits (major electives)**

| | |
|---|---|
| Psyc 77 | Drugs and Behavior (3) |
| Psyc 154 | Introduction to Clinical Psychology (3) |
| Psyc 160 | Independent Study (1-3) |
| Psyc 161 | Independent Research Seminar (1-3) |
| Psyc 171 | Learning Processes and Applications (3) |
| Psyc 176 | Introduction to Cognitive Neuroscience (3) |
| Psyc 305 | Abnormal Psychology (3) |
| Psyc 353 | Personality Theory (3) |
| Psyc 371 | Theories of Learning (3) |
| Psyc 373 | Sensation and Perception (3) |
| Psyc 376 | Physiological Psychology Laboratory (1) |
| Psyc 377 | Seminar in Physiological Psychology (3) |
| Psyc/SR 345 | Seminar on the Social Evolution of Complex Organizations (3) |
| Biol 133 | Invertebrate Zoology (3) |
| Biol 134 | Comparative Vertebrate Anatomy (4) |
| Biol 151 | Vertebrate Field Biology (3) |
| Biol 211 | Ecology (3) |
| Biol 220 | Cell Physiology (3) |
| Biol 223 | Animal Physiology (3) |
| Biol 256 | Human Genetics and Reproduction (3) |
| Biol 309 | Aquatic Biology (3) |
| Biol 313 | General Histology (3) |
| Biol 314 | Developmental Biology (3) |
| Biol 317 | Evolution (3) |
| Biol 319 | Reproduction and Mating Systems (3) |
| Biol 336 | Animal Behavior Laboratory (2) |
| Biol 338 | Endocrinology/Reproductive Physiology (3) |
| Chem 371 | Elements of Biochemistry I (3) |
| Chem 372 | Elements of Biochemistry II (3) |
| Chem 377 | Biochemistry Laboratory (3) |

**Required Courses in Math and Chemistry**

| | |
|---|---|
| Math 41, 44 | BMSS Calculus I and II (6) **or** |
| Math 21, 22 | Analytic Geometry and Calculus I and II (8) |
| Chem 21 | Introductory Chemical Principles (4) |
| Chem 22 | Chemical Principles Laboratory (1) |
| Chem 51, 52 | Organic Chemistry I and II (6) |
| Chem 53, 58 | Organic Chemistry Laboratory(2) |

## *B.S. in Behavioral and Neural Biology*

B.S. majors are required to take the core courses and *all* of the courses listed in category 1 and category 2 of the B.A. program and to fulfill the elective requirements of category 3 of the B.A. program. An early commitment to the B.S. is desirable to meet all the requirements of this program. Additional requirements are shown below.

**Math and science requirements for the B.S.**

| | |
|---|---|
| Math 21, 22, 23 | Analytic Geometry and Calculus I II & III (12) |
| Chem 21, 22 | Introductory Chemical Principles & Lab (5) |
| Chem 51, 52 | Organic Chemistry I & II (6) |
| Chem 53, 58 | Organic Chemistry Laboratory (2) |
| Chem/Biol 371 & 372 | Elements of Biochemistry I & II (6) |
| Chem 377 | Biochemistry Laboratory (3) |
| Phys 11, 12 | Introductory Physics and Laboratory (5) |
| Phys 13, 14 | General Physics and Laboratory (4) |

Phys 21, 22 (5) can substitute for Phys 13, 14.

**University and College requirements for the B.S.**

| | |
|---|---|
| Engl 1 | Composition and Literature (3) |
| Engl 2, 4, 6, 8 or 10 | Composition and Literature (3) |
| Arts and science 1 | Choices and Decisions (1) |

Nonscience Electives (30) to be broadly distributed in fields of thought other than the natural sciences and mathematics, including at least 12 credit hours each in the humanities and social sciences.

**Special Programs.** Students may apply for admission to an accelerated B.A.-doctor of medicine program and a B.A.-doctor of medical dentistry program. A six-year B.A.-M.D. program is offered in conjunction with the Medical college of Pennsylvania, and a seven-year B.A.-D.M.D. program is offered in conjunction with the University of Pennsylvania School of Dental Medicine. Students in these programs receive a B.A. from Lehigh and a graduate degree from the designated professional school within a six- or seven-year period. For details concerning admission to these programs, see Health Professions, Section III.

**Departmental Honors.** A student may apply for admission through a potential thesis advisor. Students applying in their junior year are required to have a minimum cumulative average of 3.25 for the previous 4 semesters or a minimum of 3.5 for the previous 2 semesters. Students applying in their senior year are required to have a minimum average of 3.25 for the previous 4 semesters.

**Requirements**
A minimum of 12 hours of independent study (or undergraduate research and/or special topics courses) with grades of B or better is required. No more than 6 of these 12 hours may be offered to satisfy major program requirements. A 3.25 cumulative average must be maintained in the last 3 semesters. These courses should be pursued by the student as a comprehensive, sustained research effort the results of which are documented in the required honors thesis. This thesis must be unanimously approved by an examining committee composed of the advisory committee plus a professional biologist who is not a member of the department. The main content of the thesis must be presented at a public lecture.

## *Minor in Biology*

A minor in biology may be achieved by completing the following requirements:

| | |
|---|---|
| Biol 21, 22 | Principles of Biology and Laboratory (4) |
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |
| Chem 51 | Organic Chemistry (3) |
| Math 41 | BMSS Calculus I (3) |
| | Biol electives (12) |
| | total credits 27 |

## Undergraduate Courses in Biology

**1. Biology and Society (3)**
Principles and implications of modern biological thought for nonscience, business, and engineering majors. Areas of high social relevance, such as genetics, behavior, populations, and environment. May not be substituted for or taken in addition to Biol 21.

**5. Humanistic Botany (3)**
Introduction to the botanical world for non-majors in biology. Origins, evolution, taxonomy, horticulture, ecology, physiology and reproduction in plants. Two lectures, one laboratory.

**21. Principles of Biology (3)** fall-spring
Introduction to biology by study of selected principles. Topics covered include cell structure and function, plant and animal structure and function, diversity and evolution of organisms. Three lectures per week.

**22. Introduction to Biology Laboratory (1)** fall-spring
Laboratory observations and experiments to illustrate how biological information is acquired. Designed primarily as a laboratory to accompany Biol 21. Prerequisite: Biol 21 previously or concurrently. One three-hour laboratory per week.

**28. Mendelian and Population Genetics (3)** fall-spring
Mendel's Laws of Segregation and Independent Assortment, chromosome structure, mitosis, meiosis, linkages, gender determination, sex linkage, cytoplasmic inheritance, and gene frequencies in population. Laboratory emphasizes patterns of gene transfer in *Drosopila melanogaster*. Two lectures, one laboratory.

Note: The biology curriculum is under revision, and will result in Biol 21, 22, and 28 being replaced by new core courses during the 1989-90 academic year.

**131. Non-Vascular Plants (3)** fall
A comparative study of the ontogenetic and phylogenetic development of algae, fungi, and bryophytes. The life cycles and ecological importance of representative organisms are examined. Two lectures and one laboratory. Prerequisite: Biol 21.

**132. Evolution of Vascular Plants (3)** spring
A comparative study of the ontogenetic and phylogenetic development of vascular plants. The life cycles, ecological importance and cellular morphology of the higher plants are examined. Emphasis on the plants of Pennsylvania. Two lectures and one laboratory. Prerequisite: Biol 21.

**133. Invertebrate Zoology (3)** spring
Detailed survey of representative invertebrates. Anatomical and histological examination of selected types. Concepts of evolution and speciation. Two lectures and one laboratory. Prerequisites: Biol 21 and 22 or consent of department chairperson.

**134. Comparative Vertebrate Anatomy (4)** fall
A course in vertebrate zoology with emphasis on the study of homologous body structures in the various vertebrate classes and their relationship to the functional demands of habit and environment in each class. Detailed dissections of representative vertebrates are made in the laboratory. Two lectures and two laboratory periods. Prerequisites: Biol 21 and 22 or equivalent; sophomore standing.

**151. Vertebrate Field Biology (3)**
Field studies on the diversity and distribution of local vertebrates. Emphasis on methods of sampling, collecting and identifying populations and on measurement of the physical environment. Two lectures per week, laboratories on Friday afternoon and on Saturday during the first seven weeks. Prerequisites: Biol 21, 22 and consent of the department chairperson. Enrollment limited.

**211. Ecology (3)**
Basic principles and applications of ecological interrelationships. Examination of ecological phenomena at the individual, population, community, and ecosystem levels. Two lectures and one laboratory period or field trip. Prerequisite: at least one 100 level biology course or consent of department chairperson.

**220. Cell Physiology (3)** fall
The fundamental processes of life at the cellular level emphasizing the eukaryotes. Topics include aspects of thermodynamics and biochemistry, enzyme kinetics, membrane structure and function (including exchange phenomena, receptor systems, and electrical excitability), mechanisms of motility in muscle and cilia, energy transduction in chloroplasts and mitochondria, mechanisms and regulation of protein synthesis and cell growth. Two lectures and one laboratory. Prerequisites: Biol 21, 28 and Chem 52 and Phys 11 previously or concurrently.

**223. Animal Physiology (3)** spring
The functions and structures of vertebrate and invertebrate animals, with emphasis on adaptations to marine, freshwater, and terrestrial environments. Topics include respiration, circulation, energy allocation, locomotion, osmoregulation, excretion, information acquisition via sensory organs, and coordination through nervous and endocrine systems. Two lectures, one laboratory. Prerequisite: Biol 133 or 134.

**225. Introduction to Biological Research (3)**
Literature and methods of research in area of department faculty expertise. Requires development of detailed proposal for research to be performed in senior year. Prerequisites: Major in biology, molecular biology, or behavioral and neural biology, junior standing, GPA of 3.0 in major, and consent of the department chairperson.

**235. Microbiology (3)**
The appearance, physiology and taxonomy of prokaryotes. Two lectures and one laboratory period. Prerequisite: Chem 52, previously or concurrently.

**256. Human Genetics and Reproduction (3)**
Processes and mechanisms of human heredity. Emphasis at the cellular and molecular levels. Analysis, organization, expression and evolution of human genome. Genetic aspects of reproduction and development, mapping human chromosomes, cell hybridization, molecular analysis of gene structure and function, behavior and intelligence, primate origins and evolution, immunogenetics, cancer and oncogenes, genetic technologies. Prerequisite: Biol 28.

**261. Special Topics in Biology (1-3)**
Research, conferences and reports on selected topics not covered in the general undergraduate offerings. May be taken more than once for credit. Prerequisite: consent of the department chairperson.

## For Advanced Undergraduates and Graduate Students

**309. Aquatic Biology (3)** alternate years
Physical, chemical and biological aspects of fresh-water environment, including cyclic and seasonal changes. Major groups of organisms and their interactions. Two lectures and one laboratory or field trip. Prerequisite: Biol 21 or consent of the department chairperson.

**313. General Histology (3)**
The techniques of preservation and preparation of animal and plant tissues for microscopical study; comparative studies of fresh and preserved tissues. Two lecture-laboratory periods. Prerequisite: Biol 134 or consent of the department chairperson.

**314. Developmental Biology (3)**
Germ cell formation, fertilization, early development and the origin of the principal organ systems of vertebrates. Molecular basis of developmental processes, particularly the location, structure and regulation of information in developing animals. Two lectures and one laboratory per week. Prerequisite: Biol 133 or 134 and 220 or 223.

**317. (Geol 317) Evolution (3)**
Mechanisms of evolution, emphasizing genetic structure and variation of populations, and isolation. Origin of species and higher taxa. Rates of evolution, extinction. Prerequisites: Biol 28 and any two 100 level biology courses.

**325. Topics in Genetics (3)**
Lectures and student projects on selected aspects of genetics: the genetics and evolution of particular organisms, regulation of gene transmission, behavior genetics, human evolution and genetics. Prerequisite: Biol 345 or consent of department chairperson.

**327. Cellular Regulation (3)**
Systems of regulation of cellular activity and multicellular coordination; cell replication, movements and integration of activity within and between cells. Two lectures, one laboratory. Prerequisite: Biol 220.

**329. Herpetology (3)**
Biology of amphibians and reptiles. Two lectures, one laboratory or field trip per week. Prerequisite: Biol 134.

**335. (Psyc 335) Animal Behavior (3)**
Discussion of the behavior of invertebrates and vertebrates and analysis of the physiological mechanisms responsible for behavioral stimuli, and adaptive value of specific behavior patterns. Prerequisite: Biol 21 or consent of the department chairperson.

**336. Animal Behavior Laboratory (2)**
Experiments and field observations illustrating principles discussed in Biol 335. Emphasis on observing animals, performing experiments, collecting and analyzing data, and individual research. Six hours of laboratory per week. Corequisite: Biol 335 or 337. Limited enrollment.

**337. (Psyc 337) Sociobiology (3)**
Social systems of vertebrate and invertebrate groups. Emphasis on ecological and evolutionary factors that influence social behavior. Prerequisite: Biol 21 or consent of department chairperson.

**338. Endocrinology/Reproductive Physiology (3)**
Lectures and discussions designed to provide a broad background in mammalian endocrinology and reproductive physiology from the molecular to the organismic level. Emphasis will be placed on hormone and drug receptor mechanisms and biochemical basis of hormone and related drug actions. Prerequisites: Biol 220 or 223, and Chem 371.

**345. Molecular Genetics (3)**
The organization and replication of genetic material; mutagenesis; mechanisms of regulation; mechanisms of gene transmission involving prokaryotes and eukaryotes and their viruses; techniques for intervention into genetic organization and expression. Two lectures and one laboratory. Prerequisites: Biol 28, 220 and 235 or consent of the department chairperson.

**353. Virology (3)**
Structure and replication of viruses, including those infecting bacteria, plants and animals. Emphasis on the organization, replication and regulation of expression of viral geonomes and on the mechanisms of virus assembly and release. Special attention given to human pathogenic viruses. Prerequisite: Biol 220, 235, and Chem 371.

**367. Molecular and Cellular Biophysics (3)**
Physico-chemical aspects of modern molecular and cellular biology, with emphasis on the structure and dynamics of nucleic acid complexes and membranous intracellular organelles. A study of the physical basis of techniques for biomolecular analysis. Prerequisite: Biol 220, 235, and Chem 371.

**371. (Chem 371) Elements of Biochemistry I (3)** fall
A general study of carbohydrates, proteins, lipids, nucleic acids and other biological substances and their importance in life processes. Protein and enzyme chemistry are emphasized. Prerequisite: one year or organic chemistry.

**372. (Chem 372) Elements of Biochemistry II (3)** spring
Dynamic aspects of biochemistry; enzyme reactions including energetics, kinetics and mechanisms; metabolism of carbohydrates, lipids, proteins and nucleic acids; photosynthesis, electron transport mechanisms, coupled reactions, phosphorylations, and the synthesis of biological macromolecules. Prerequisite: Chem 371.

**375. (Psyc 375) Neuroanatomy of Behavior (3)** fall
Neuroanatomy and neurophysiology of animal and human behavior. Feeding, thirst, sleep, emotions, learning, and psychopathology. Prerequisite: Psych 177 or Biol 220 or 223 or 335.

**376. (Psyc 382) Endocrinology of Behavior (3)** spring
Hormonal effects upon animal and human behavior. Emphasis on neuroendrocrinology of steroid hormone involvement in reproductive behaviors. Prerequisite: Psych 178 or Biol 220 or 223 or 335.

**391. Undergraduate Research (3)**
Laboratory and/or field research under tutorial with a faculty member. May be taken more than once for credit. Prerequisites: junior standing and at least 5 completed courses in biology, including Biol 225, a cumulative average of 3.0 in the major and consent of chairperson.

## Graduate Study in Biology

The Biology Department accepts a limited number of students who are interested in graduate study towards the master of science or doctor of philosophy degrees in biology or molecular biology. Students entering the program with a bachelor's degree must complete the M.S. degree, including submission of an acceptable master's thesis, before proceeding to the Ph.D. program. Because of the small number of department staff members and the restricted number of graduate students, staff and students work together closely, especially during the years of student specialization.

Departmental research thrusts are focused in two general areas; environmental/organismal and cellular/molecular biology. Environmental/organismal research includes: functional morphology of feeding in reptiles; organismal energetics; aquatic toxicology, including fate and effect of atmospheric pollutants; marine and freshwater zooplankton ecology; dynamics of aquatic food chains; predator-prey interactions; sociobiology of coral reef and freshwater fishes. Cellular/molecular biology research includes: properties of motile cells; microbial evolution; physiology and

genetics of microorganisms oriented to biotechnology; plant and developmental molecular genetics; reproductive cell biology; and virology.

Each entering student is initially guided by his or her own faculty committee. A separate M.S. or Ph.D. committee later directs progress towards the advanced degree and tailors the program to fit special needs and interests of the student. Within the Ph.D. program there are three formal examinations, the qualifying exam, the general exam, and the dissertation defense.

The prerequisite for graduate work in biology is undergraduate training in biology, chemistry, physics, and mathematics approximately equivalent to that taken by biology majors at Lehigh University. Minor deficiencies in these areas may be completed during the first year of graduate study—usually, however, without graduate credit. Candidates for admission to graduate study in biology must take the Graduate Record Examination Advanced test in biology as well as the GRE Verbal and Quantitative tests. Failure to include results of these examinations with the application for admission can seriously delay or prevent action on the application.

## Graduate Courses in Biology

**402. Comparative Animal Physiology (3)**
Lectures and seminars on selected areas in the comparative physiology of animals. Introduction to the current literature of subjects studied. These include mechanisms of osmotic control, temperature effects, nerve and muscle physiology and others. Prerequisite: Biol 220 or 223.

**405. Special Topics in Biology (3)**
Research, conferences, and reports on selected topics not covered in the general graduate offerings. May be taken more than once for credit.

**406. Biological Seminar (1)**
An advanced seminar in current developments including departmental research. Required for candidates for graduate degrees. May be taken more than once for credit.

**407. Biological Research (1-9)**
Investigations in any phase of the biological sciences according to the student's preparation and interests.

**409. Advanced Morphology (3)**
A laboratory course in special phases of morphology, such as comparative osteology, comparative morphology or embryology of the vertebrates, etc., to meet the individual interests of the student.

**414. Advanced Ecology (3)**
Seminars, conferences and directed field work with emphasis on theoretical models and their application to real biological systems. May be taken more than once for credit. Prerequisite: consent of the department chairperson.

**415. Cytochemistry (3)**
A study of morphological and biochemical events during cell growth and differentiation including lectures, laboratories, and student reports on current literature. Special emphasis is placed on developmental patterns and laboratory procedures of the cytochemist. Prerequisite: consent of the department chairperson.

**418. Biological Oceanography (3)**
Surveys of marine plant and animal plankton; nekton and benthos. Composition of various groups, productivity, interrelationships of plants and animals and the role of microorganisms in the sea. Prerequisite: consent of the department chairperson.

**419. Analysis of Reproduction and Mating Systems (3)**
Study of reproduction and sexuality in plants and animals with emphasis on current hypotheses as reported in the literature. Topics include hermaphroditism, neoteny, larval forms, parental investment, complex life cycles, population structure. Lecture sections may be in common with Biol 319. Readings from primary source material and review articles. One review paper and one research proposal are required, and together with readings forms the basis for discussion sections and examinations. Prerequisite: consent of the department chairperson. Not open to students who have taken Biol 319.

**424. Community Ecology (3)**
Current concepts in the ecology of animal communities. Theoretical and experimental approaches to understanding the primary factors which regulate the structure and dynamics of communities. Focus on biotic interactions (competition and predation). Prerequisite: Biol 211 or equivalent.

**429. Advances in Herpetology (3)**
Lectures and readings from the primary literature on current research in amphibian and reptilian biology. Two lectures, one discussion session and one laboratory or field trip. In addition, a week-long field trip during spring vacation is required. Not open to students who have received credit for Biol 329.

**437. Advanced Sociobiology (3)**
Critical evaluation of the theoretical foundation in sociobiology. Emphasis placed on kinship, altruism, mate choice, parental investment, parent-offspring conflict, etc. Lectures and seminars. Not open to students who have taken Biol 337.

**441. Marine Botany (3)**
A study of the morphological, physiological, biochemical and ecological features of those plants found primarily in the salt water environment. Emphasis is placed on the evolutionary and ecological significance of the phytioplankton, benthic algae and rooted aquatic plant divisions associated in and near the oceans. The economic importance of these plants is considered. Laboratory work, field work and library searches and reports.

**442. Marine Zooplankton (3)**
A comprehensive study of neritic and oceanic plankton. Studies on the life history, morphology and distribution of both holoplanktonic and meroplanktonic animals. Prerequisite: consent of the department chairperson.

**443. Ichthyology (3)**
Lectures and laboratory on the anatomy, physiology, behavior and taxonomy of marine and fresh-water fishes.

**444. (Geol 444) Multivariate Analysis (3)**
The strategy of the application of multivariate analysis techniques to problems in geology and biology. Analysis of large data matrices by factor analysis, cluster analysis, discriminant function analysis, ordination, and related techniques. Examples from both geology and biology. Prerequisites: Geol 10 and Geol 321 or approved equivalents.

**461. Molecular Cell Biology I (3)**
An advanced course covering the molecular structures and mechanisms involved in cell physiology, including genome structure and replication, RNA synthesis/processing, protein synthesis and transport, biomembranes, and determination of cell structure.

**462. Molecular Cell Biology II (3)**
A continuation of Biol 421, with emphasis on developmental cell biology, molecular aspects of reproduction and disease, and biotechnology.

**463. Biomolecular Laboratory Techniques (3)**
A laboratory course on up-to-date techniques for the analysis of nucleic acids and proteins.

**464. Ultrastructure Laboratory Techniques (3)**
A lecture-laboratory course on modern capabilities for ultra-high resolution structural analysis of biological systems.

**465. Topics in Molecular Biology (1-3)**
Advanced seminar in areas of molecular biology; may be repeated when a different topic is offered.

**466. Topics in Cell and Developmental Biology (1-3)**
Advanced seminar in areas of cellular and developmental biology; may be repeated when a different topic is offered.

# Chemical Engineering

**Professors.** John C. Chen, Ph.D. (Michigan), *chairman and Carl R. Anderson Professor;* Fred P. Stein, Ph.D. (Michigan), *associate chairman;* Philip A. Blythe, Ph.D. (Manchester, England); Hugo S. Caram, Ph.D. (Minnesota); Marvin Charles, Ph.D. (Brooklyn Polytechnic); Mohamed S. El-Aasser, Ph.D. (McGill); Christos Georgakis, Ph.D. (Minnesota); Arthur E. Humphrey, Ph.D. (Columbia), *T. L. Diamond Professor of Biotechnology;* William L. Luyben, Ph.D. (Delaware); Matthew J. Reilly, Ph.D. (Illinois); Eric P. Salathe, Ph.D. (Brown); William E. Schiesser, Ph.D. (Princeton), *McCann Professor;* Leslie H. Sperling, Ph.D. (Duke).
**Associate professors.** James T. Hsu, Ph.D. (Northwestern); Andrew Klein, Ph.D. (North Carolina State); Janice A. Phillips, Ph.D. (Pennsylvania); Cesar A. Silebi, Ph.D. (Lehigh); Harvey G. Stenger, Jr., Ph.D. (M.I.T.); Israel E. Wachs, Ph.D. (Stanford).
**Adjunct professors.** Jacob M. Geist, Ph.D. (Michigan); William R. Hencke, M.S.E. in ChE (Michigan).
**Adjunct associate professors.** Montford S. Benson, Ph.D. (Missouri); Paul M. Mathias, Ph.D. (Florida).
**Research engineers.** E. David Sudol, Ph.D. (Lehigh); Kemal Tuzla, Ph.D. (Technical University of Istanbul).
**Emeritus professors.** Curtis W. Clump, Ph.D. (Carnegie-Mellon); Leonard A. Wenzel, Ph.D. (Michigan).

Chemical engineers serve a wide variety of technical and managerial functions within the chemical processing industry. For a lifetime of effectiveness they need a sound background in the fundamental sciences of chemistry and physics, a working capability with mathematics, numerical methods, and application of computer solutions, and a broad education in humanities, social sciences, and managerial techniques.

These bases are applied in a sequence of courses called chemical engineering in which logic and mathematical manipulation are applied to simulated chemical processing problems.

With the resulting habits of precise thought coupled to a broad base in scientific and general education, Lehigh graduates have been effective throughout industry and in advanced professional education. No effort is made in orientation toward any specific industry, but adaptation is rapid and the fundamental understanding forms the base for an expanding career.

The program is also designed to prepare a student for graduate study in chemical engineering. Further study at the graduate level leading to advanced degrees is highly desirable if an individual wishes to participate in the technical development of the field. The increasing complexity of modern manufacturing methods requires superior education for men and women working in research, development, and the design fields or for teaching.

**Physical facilities.** The Chemical Engineering Department was selected as the first engineering department to move into expanded facilities on Lehigh's newly acquired 780-acre Mountaintop Campus. Here the Department occupies approximately one-third of Building A, the 200,000-square-foot flagship building that contains offices, classrooms, and laboratories. Additional pilot-plant facilities will occupy approximately 10,000-square-feet of an adjacent engineering-test building.

These facilities provide excellent support for a wide range of general laboratory equipment for undergraduate study of the behavior of typical chemical processing units; special equipment for biochemical engineering and for the study of polymers; digital computation for process dynamics study; and special equipment for the study of thermodynamics, kinetics, heat transfer, and mass transfer.

## *Career Opportunities*

Chemical engineers play important roles in all activities bearing on the chemical process industry. These include the functions of research, development, design, plant construction, plant operation and management, corporate planning, technical sales, and market analysis.

The industries that produce chemical and/or certain physical changes in fluids, including petroleum and petrochemicals, rubbers and polymers, pharmaceuticals, metals, industrial and fine chemicals, foods, and industrial gases, have found chemical engineers to be vital to their success. Chemical engineers are also important participants in pollution abatement, energy resources, and national defense programs.

## *Special Programs and Opportunities*

The department operates a cooperative program that is optional for specially selected students who are in their sophomore year. This program affords early exposure to industry and an opportunity to integrate an academic background with significant periods of engineering practice.

Opportunities for undergraduate involvement in research projects, design projects, and programs of independent study are many, but are usually arranged specifically between a student and a professor. The curricular flexibility encourages the student to emphasize an area of special interest in the selection of electives. In some cases these electives lead to a minor in addition to the chemical engineering major.

## Requirements of the Major

**freshman year:** see Recommended Freshman Year, page 46.

**sophomore year, first semester** (18 credit hours)

| | |
|---|---|
| ChE 43 | Introduction to Chemical Engineering (4) |
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| Eco 1 | Economics (4) |
| | elective (3) |

**sophomore year, second semester** (18 credit hours)

| | |
|---|---|
| ChE 44 | Chemical Process Analysis I (4) |
| Math 205 | Linear Methods (3) |
| Chem 187 | Physical Chemistry I (3) |
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |
| | elective (3) |

**junior year, first semester** (16 credit hours)

| | |
|---|---|
| ChE 141 | Chemical Process Analysis II (4) |
| Chem 51 | Organic Chemistry (3) |
| Chem 53 | Organic Chemistry Laboratory (1) |
| Chem 189 | Physical Chemistry II (3) |
| Chem 192 | Physical Chemistry Laboratory (2) |
| | elective (3) |

**junior year, second semester** (17 credit hours)

| | |
|---|---|
| ChE 142 | Chemical Process Analysis III (4) |
| ChE 202 | Chemical Engineering Laboratory I (3) |
| ChE 210 | Chemical Engineering Thermodynamics (4) |
| Chem 52 | Organic Chemistry (3) |
| | elective (3) |

**senior year, first semester** (17 credit hours)

| | |
|---|---|
| ChE 203 | Chemical Engineering Laboratory II (2) |
| ChE 211 | Chemical Reactor Design (3) |
| | electives (12) |

**senior year, second semester** (18 credit hours)

| | |
|---|---|
| ChE 233 | Process/Plant Design (3) |
| ECE 81 | Principles of Electrical Engineering (4) |
| | electives (11) |

The total number of credits required for graduation is 134.

A total of 38 credits in electives must be taken. These electives are of six types:

(a) General Studies: A total of 15 hours of electives in humanities and social science. (Note that these electives are in addition to the 10 hours of required General Studies.)

(b) Courses in Other Engineering Departments (CE, ECE, IE, MEM, MAT): A total of 8 credit hours is required.

(c) Chemistry: 3 credit hours of 200-level or higher.

(d) Science: 3 credit hours in any course in chemistry, mathematics, physics, biology or geology.

(e) Chemical Engineering (only ChE 185, 186, 300-level, or 400-level courses are acceptable) or Science (only 200-level or higher in departments listed in (d) above are acceptable): 3 credit hours. (Cross-listed courses used for other electives or requirements are not acceptable.)

(f) Free electives: 6 credit hours in any subject area (including advanced chemical engineering) are required.

## Undergraduate Courses

**43. Introduction to Chemical Engineering (4)** fall
Material and energy balances with and without chemical reaction. Applications in chemical process calculations and in design of separations cascades, especially distillation. Plant trips and special lectures introductory to the profession.

**44. Chemical Process Analysis I (4)** spring
Fluid mechanics and its applications to chemical processes. Momentum and energy balances in fluid flow. Dimensional analysis. Fluid flow in pipes, packed and fluidized beds. Mixing and agitation. Filtration and sedimentation. Three lectures and one calculation period per week.

**60. Unit Operations Survey (3)** fall
The theory of heat, mass and momentum transport. Laminar and turbulent flow of real fluids. Heat transfer by conduction, convection, and radiation. Application to a wide range of operations in the chemical and metallurgical process industries.

**141. Chemical Process Analysis II (4)** fall
Fundamental principles of heat and mass transfer. Application of these transport fundamentals and conservation laws to the analysis and design of chemical processing units involving heat and/or mass transfer. Prerequisite: ChE 43 and ChE 44.

**142. Chemical Process Analysis III (4)** spring
Review of the physical and chemical laws that are the basis for the mathematical modeling of dynamic chemical engineering systems. Digital computer solution techniques for mathematical models expressed as systems of algebraic, ordinary and partial differential equations. Introduction to process control equipment and stability analysis. Review of Laplace Transforms, transfer functions, block diagrams and linearization. Prerequisite: ChE 141 and Math 205.

**179. Professional Development (1)** fall
Elements of professional growth, registration, ethics, and the responsibilities of engineers both as employees and as independent practitioners. Proprietary information and its handling. Patents and their importance. Discussions with the staff and with visiting lecturers. A few plant trips. Prerequisite: junior standing.

**185. Undergraduate Research I (3)**
Independent study of a problem involving laboratory investigation, design, or theoretical studies under the guidance of a senior faculty member.

**186. Undergraduate Research II (3)**
A continuation of the project begun under ChE 185. Prerequisite: ChE 185 or consent of the department chairperson.

**202. Chemical Engineering Laboratory I (3)** spring
The laboratory study of chemical engineering unit operations and the reporting of technical results. One three-hour laboratory and one lecture period per week. Independent study and both group and individual reporting. Prerequisite: ChE 141.

**203. Chemical Engineering Laboratory II (2)** fall
Laboratory experience with more complex chemical processing situations including processes involving chemical reactions and those controlled automatically. Prerequisite: ChE 142.

**207. (Math 207) Introduction to Biomedical Engineering and Mathematical Physiology (3)** fall
Topics in human physiology and mathematical analysis of physiological phenomena, including the cardiovascular and respiratory systems, biomechanics, and renal physiology; broad survey of bioengineering. Independent study projects. Prerequisite: Math 205.

**210. Chemical Engineering Thermodynamics (4)** spring
Energy relations and their application to chemical engineering. Consideration of flow and nonflow processes. Evaluation of the effects of temperature and pressure on the thermodynamic properties of fluids. Heat effects accompanying phase changes and chemical reactions. Determination of chemical and physical equilibrium. Prerequisite: Chem 187 or equivalent.

**211. Chemical Reactor Design (3)** fall
The application of chemical kinetics to the design and operation of chemical reactors. Plug flow and continuous stirred tank reactors. Homogeneous and heterogeneous reaction kinetics. Design of isothermal and adiabatic reactors. Prerequisite: ChE 141, ChE 210 or equivalent.

**233. Process/Plant Design (3)** spring
Economic principles involved in the selection of process alternates and determination of process operation costs. Preliminary design of chemical plants including optimization of process configuration, market limitations on plant planning, environmental and regulatory restrictions. Prerequisite: ChE 141 and ChE 210.

## For Advanced Undergraduates and Graduate Students

**301. Process Design (3)** fall
Study of the strategy of chemical process design with emphasis on optimum order of steps, flow diagrams, energy balances, recycle ratios and their effect on the economics of the operation. Survey of methods for ordering equations. Discussion of process optimization for nonlinear systems. Effects of uncertainty in process design.

**312. (Chem 312, Mat 312) Fundamentals of Corrosion (3)** fall
Corrosion phenomena and definitions. Electrochemical aspects including reaction mechanisms, thermodynamics, Pourbaix diagrams, kinetics of corrosion processes, polarization, and passivity. Non-electrochemical corrosion including mechanisms, theories, and quantitative descriptions of atmospheric corrosion. Corrosion of metals under stress. Cathodic and anodic protection, coatings, alloys, inhibitors, and passivators. Prerequisite: Met 210, Chem 187, or equivalent. Leidheiser or Smyth

**320. Waste Water Control (3)**
The physical processes of importance in the design of industrial waste-water treatment facilities. Topics will include sedimentation and filtration processes as well as advanced methods such as adsorption, ion exchange, osmosis, foaming, freezing, and hydrate formation. Prerequisite: ChE 211.

**321. Fundamentals of Air Pollution (3)**
Introduction to the problems of air pollution including such topics as: sources and dispersion of pollutants; sampling and analysis; technology of economics and control processes; legislation and standards. Prerequisite: senior standing in the College of Engineering and Applied Sciences.

**331. Separation Processes (3)** spring, every other year
Industrial separation chemistry and processes. Computer solutions for simple and complex multicomponent distillation columns. Azeotropic and extractive distillation. Adsorption, ion exchange and chromatography in packed beds, moving beds and cyclic operation. Synthesis of polymer membrane and its applications to industrial separation processes. Hsu and Luyben.

**335. (Mat 335) Principles of Semiconductor Materials Processing (3)**
Description and analysis of the processing steps involved in microelectronic material fabrication. Emphasis will be placed on the chemistry of the fabrication steps, mathematical modeling of the transport and chemical reaction phenomena, and interpretation of experimental methods and data. Prerequisites: a course in thermodynamics, and senior standing.

**341. Biotechnology I (3)** fall
Applications of material and energy balances; heat, mass, and momentum transfer; enzyme and microbial kinetics; and mathematical modeling to the engineering design and scale-up of bio-reactor systems. Prerequisites: Math 22, Phys 11, and Chem 187; or the equivalent of each and the consent of the instructor.

**342. Biotechnology II (3)** spring
Engineering design and analysis of the unit operations used in the recovery and purification of products manufactured by the biotechnology industries. Requirements for product finishing and waste handling will be addressed. Prerequisite: ChE 341 or equivalent.

**350. Special Topics (1-3)**
A study of areas in chemical engineering not covered in courses presently listed in the catalog. May be repeated for credit if different material is presented.

**360. (ME 360) Nuclear Reactor Engineering (3)**
A consideration of the engineering problems in nuclear reactor design and operation. Topics include reactor fuels and materials, thermal aspects, instrumentation and control problems, radiation protection and shielding, fuel processing, and reactor design. Prerequisite: senior standing in the College of Engineering and Applied Sciences.

**370. Process Safety and Hazard Analysis (3)** spring
A study of the methodology now available for analyzing hazard frequency and level in chemical processes. Applications to real process examples using hazard and operability analysis, fault tree and event tree analysis, "what if" analysis, and preliminary hazard analysis. Also includes a survey of the field of industrial safety.

**380. Design Projects (1-6)** fall-spring
Design project work as a member of a team preferably including students from different disciplines. The project attacks a problem which, when possible, involves one of the local communities or industries. Specific projects are normally guided by faculty from several departments with consultants from off the campus. The course may be repeated for credit.

**386. Process Control (3)** fall
Laplace transformation and transfer functions, frequency response, feedback, and feedforward control. Open loop and closed-loop stability analysis using root locus and nyquist techniques, design of feedback controllers with time and frequency domain specifications. Experimental process identification, introduction to sampled-data control theory. Prerequisite: ChE 142 or equivalent.

**387. (ECE 387, ME 387) Digital Control (3)** spring
Sampled-data systems; z-transforms; pulse transfer functions; stability in the z-plane; root locus and frequency response design methods; minimal prototype design; digital control hardware; discrete state variables; state transition matrix; Liapunov stability state feedback control (2 lectures and one laboratory per week). Prerequisite: ChE 386 or ECE 212 or ME 342 or consent of instructor.

**388. (Chem 388) Polymer Synthesis and Characterization Laboratory (3)** spring
Techniques include: free radical and condensation polymerization; molecular weight distribution by gel chromatography; crystallinity and order by differential scanning calorimetry; pyrolysis and gas chromatography; dynamic mechanical and dielectric behavior; morphology and microscopy; surface properties. Prerequisite: Chem 51, 187 or 191.

**392. (Chem 392) Polymer Science (3)** spring
Introduction to concepts of polymer science. Kinetics and mechanism of polymerization, synthesis and processing of polymers, characterization. Relationship of molecular conformation, structure and morphology to physical and mechanical properties. Prerequisite: Chem 187 or equivalent.

**393. (Chem 393, Mat 343) Physical Polymer Science (3)** fall
Structural and physical aspects of polymers (organic, inorganic, natural). Molecular and atomic basis for polymer properties and behavior. Characteristics of glassy, crystalline, and paracrystalline states (including viscoelastic and relaxation behavior) for single and multicomponent systems. Thermodynamics and kinetics of transition phenomena. Structure, morphology, and behavior. Prerequisite: Mat 63 or one year of physical chemistry.

**394. (Chem 394) Organic Polymer Science (3)** spring
Organic chemistry of synthetic high polymers. Functionality and reactivity of monomers and polymers. Theory of stepgrowth and chaingrowth polymerization in homogeneous and heterogeneous media. Polymerization by addition, elimination, substitution and coupling reactions. Ionic free-radical and coordinate catalysis. Prerequisite: one year of physical chemistry and one year of organic chemistry.

## Graduate Programs

The department of chemical engineering offers graduate programs leading to the master of science, master of engineering, and doctor of philosophy degrees. The programs are all custom tailored for individual student needs and professional goals. These individual programs are made possible by a diversity of faculty interests that are broadened and reinforced by cooperation between the department and several research centers on the campus.

A free flow of personnel and ideas between the centers and academic departments insures that the student will have the widest choice of research activities. The student is also exposed to a wide range of ideas and information through courses and seminars to which both faculty and center personnel contribute. In addition, strong relationships with industry are maintained by the department and the research centers, some of which operate industrially sponsored liaison programs whereby fundamental nonproprietary research is performed in areas of specific interest to participating sponsors.

While the department has interacted with most of the centers on campus, it has had unusually strong and continuing liaisons with Emulsion Polymers Institute, Process Modeling and Control Research Center, Institute for Thermo Fluid Engineering and Science, Materials Research Center, Center for Surface and Coatings Research, and the Biotechnology Research Center.

In addition to interacting with the centers, the department originates and encourages programs that range from those that are classical chemical engineering to those that are distinctly interdisciplinary. The department offers active and growing programs in: emulsion polymerization and latex technology; bulk polymer systems; process control; process improvement studies; rheology; computer applications; environmental engineering; thermodynamics; kinetics and catalysis; enzyme technology; and biochemical engineering.

### *Career Opportunities*

Master of science and doctor of philosophy graduates in the chemical engineering area are sought by industry for activities in the more technical aspects of their operations, especially design, process and product development, and research. Many of these graduates also find opportunities in research or project work in government agencies and in university teaching and research.

### *Physical Facilities*

The department is well equipped for research in polymer science and engineering, catalysis and reaction kinetics, thermodynamic property studies, fluid dynamics, heat and mass transfer, process dynamics and control, and enzyme engineering and biochemical engineering.

The Departmental and University computing facilities, including microcomputers, computer interfaces, and mainframes, are used for research purposes themselves or in support of the experimental facilities.

In addition, the Chemical Process Modeling and Control Research Center operates a CYBER 810 computer system with several high and ultra high resolution terminals ideally suited for graphical representations.

## *Special Programs*

**Master of engineering design option.** For those interested in design, the department offers the master of engineering design option. In this program, the student works on a design project proposed by the process design group of a cooperating industry. Direction of the design project is shared by the cooperating industry and a member of the faculty. Students desiring to enroll in this program should indicate that fact at the time they apply for admission.

**Polymer science and engineering.** The polymers activity includes work done in the Materials Research Center, the Center for Surface and Coatings Research, the Emulsion Polymers Institute, the department of chemistry, and the department of chemical engineering.

About a dozen faculty members from these organizations or areas have major interests in polymers and cooperate on a wide range of research projects. For students with deep interest in the area, degree programs are available leading to the master of science and doctor of philosophy degrees in polymer science and engineering.

Research activities in which chemical engineering students and faculty are involved include a major study of impregnation of bridge decks with polymers to increase surface life; studies of the mechanism of kinetics of emulsion polymerization and copolymerization, colloidal surface and interfacial aspects of emulsion polymers, and the process involved in their preparation, with special attention to the relationship between process parameters and properties of polymers; work on polymer blends, especially interpenetrating networks, and the application of these materials to sound-deadening; rheology of viscoelastic materials; crystallization behavior from polymer melts and solutions; polymer film characteristics and the tailoring of these properties for selective transfer rates; latex film drying rates; coatings and the hiding capabilities of micropores; and the preparation of polymeric materials from agricultural raw materials.

**Master of engineering degree.** Students may earn the master of engineering degree in chemical engineering upon completion of a course of study and an engineering project meeting all the requirements of the master of science degree. The master of engineering student, however, elects courses closer to engineering practice, and carries out a project of more practical engineering flavor than that of the M.S. candidate. In some cases the project of the master of engineering student will be done in close collaboration with local industry, as noted above.

## Major Requirements

The requirements for the master of science degree are listed in the section on The Graduate School. All candidates for the M.S. degree are required to complete a master of science research report for which three to six hours of graduate credit are earned. Course selection is done individually for each student, although ChE 400 and ChE 415 are required courses.

The requirements for the doctor of philosophy degree also are listed in the section on The Graduate School. In addition to an approved course and thesis program, the Ph.D. student is expected to pass a qualification examination given within the first year of doctoral-level study and to pass a general examination based on a research problem presented by the student.

## Advanced Courses in Chemical Engineering

**400. Chemical Engineering Thermodynamics (3)** fall
Applications of thermodynamics in chemical engineering. Topics include energy and entropy, heat effects accompanying solution, flow of compressible fluids, refrigeration including solution cycles, vaporization and condensation processes, and chemical equilibria. Prerequisite: an introductory course in thermodynamics. Stein, Wenzel

**401. Chemical Engineering Thermodynamics II (3)** spring, every other year
A detailed study of the uses of thermodynamics in predicting phase equilibria in solid, liquid, and gaseous systems. Fugacities of gas mixtures, liquid mixtures, and solids. Solution theories; uses of equations of state; high-pressure equilibria. Stein, Wenzel

**410. Chemical Reaction Engineering (3)** spring
The application of chemical kinetics to the engineering design and operation of reactors. Non-isothermal and adiabatic reactions. Homogeneous and heterogeneous catalysis. Residence time distribution in reactors. Prerequisite: ChE 211. Klein, Georgakis

**413. Heterogeneous Catalysis and Surface Characterization (3)** fall
History and concepts of heterogeneous catalysis. Surface characterization techniques, and atomic structure of surfaces and adsorbed monolayers. Kinetics of elementary steps (adsorption, desorption, and surface reaction) and overall reactions. Catalysis by metals, metal oxides, and sulfides. Industrial applications of catalysis: selective oxidation, pollution control, ammonia synthesis, hydrogenation of carbon monoxide to synthetic fuels and chemicals, polymerization, hydrotreating, and cracking. Wachs

**415. Transport Processes (3)** fall
A combined study of the fundamentals of momentum transport, energy transport and mass transport and the analogies between them. Evaluation of transport coefficients for single and multicomponent systems. Analysis of transport phenomena through the equations of continuity, motion, and energy. Caram, Silebi

**419. (Mech 419) Asymptotic Methods in the Engineering Sciences (3)**
Introductory level course with emphasis on practical applications. Material covered includes: Asymptotic expansions. Regular and singular perturbations; asymptotic matching. Boundary value problems; distinguished limits. Multiple scale expansion. W.K.B. Theory. Far field theories. Blythe

**421. Heat Transfer (3)**
Analysis of steady and unsteady state transfer. Convection, conduction, and radiation. Vaporization and condensation. Heat transfer in high velocity flow in rarified gases. Applications. Clump, Chen

**427. (ME 427) Multiphase Heat Transfer (3)**
Heat transfer and fluid dynamics of multiphase systems. Subcooled, nucleate, and film boiling; bubble nucleation; dynamics of bubble growth and collapse; vapor-liquid cocurrent flow regimes; two-phase pressure drop and momentum exchange, low instabilities; convective-flow boiling; simultaneous heat and mass transfer. Prerequisite: ChE 421 or ME 321, or courses in the area of transport phenomena. Chen

**428. Rheology (3)**
An intensive study of momentum transfer in elastic viscous liquids. Rheological behavior of solution and bulk phase polymers with emphasis on the effect of molecular weight, molecular weight distribution and branching. Derivation of constitutive equations based on both molecular theories and continuum mechanics principles. Application of the momentum equation and selected constitutive equations to geometries associated with viscometric flows. Silebi

**430. Mass Transfer (3)** spring
Theory and developments of the basic diffusion and mass transfer equations and transfer coefficients including simultaneous heat and mass transfer, chemical reaction and dispersion effects. Applications to various industrially important operations including continuous contact mass transfer, absorption, humidification, etc. Brief coverage of equilibrium stage operations as applied to absorption and to binary and multicomponent distillation. Caram, Silebi

**433. (ECE 433, ME 433) State Space Control (3)** fall
State-space methods of feedback control system design and design optimization for invariant and time-varying deterministic, continuous systems; pole positioning, observability, controllability, modal control, observer design, the theory of optimal processes and Pontryagin's Maximum Principle, the linear quadratic optimal regulator problem, Lyapunov functions and stability theorems, linear optimal openloop control; introduction to the calculus of

variations; introduction to the control of distributed parameter systems. Intended for engineers with a variety of backgrounds. Examples will be drawn from mechanical, electrical and chemical engineering applications. Prerequisite: M.E. 343 or E.C.E. 212 or Ch.E. 386 or consent of instructor. Johnson, Georgakis

**434. (ECE 434, ME 434) Multivariable Process Control (3)**
A state-of-the-art review of multivariable methods of interest to process control applications. Design techniques examined include loop interaction analysis, frequency domain methods (Inverse Nyquist Array, Characteristic Loci and Singular Value Decomposition) feedforward control, internal model control and dynamic matrix control. Special attention is placed on the interaction of process design and process control. Most of the above methods are used to compare the relative performance of intensive and extensive variable control structures. Prerequisite: Ch.E. 433 or M.E. 433 or E.C.E. 433 or consent of instructor. Georgakis

**436. (ECE 436, ME 436) Systems Identification (3)**
The determination of model parameters from time-history and frequency response data by graphical, deterministic and stochastic methods. Examples and exercises taken from process industries, communications and aerospace testing. Regression, quasilinearization and invariant-imbedding techniques for nonlinear system parameter identification included. Prerequisite: Ch.E. 433 or M.E. 433 or E.C.E. 433 or consent of instructor. Johnson

**437. (ECE 437, ME 437) Stochastic Control (3)**
Linear and nonlinear models for stochastic systems. Controllability and observability. Minimum variance state estimation. Linear quadratic Gausian control problem. Computational considerations. Nonlinear control problem in stochastic systems. Prerequisite: Ch.E. 433 or M.E. 433 or E.C.E. 433 or consent of instructor.

**438. Process Modeling and Control Seminar (1)**
Presentations and discussions on current methods, approaches, and applications. Credit cannot be used for the M.S. degree.

**440. Process Design (3)**
Synthesis of flow sheets for various processes, investigation of contributions to overall economy of various alternatives. Evaluation of profitability of alternatives.

**444. Bioseparations (3)** fall, every other year
Separation techniques for biomolecule isolation and purification. Theory and problems of bioaffinity chromatography, electromigration processes, and aqueous two-phase polymer extraction systems. Engineering principles for scaling up bioseparation processes. Prerequisite: Consent of the instructor.

**445. Enzyme Engineering (3)** fall, every other year
Enzyme characteristics including nomenclature, physical properties, kinetics, and assay methods with emphasis on practical application at commercial scale. Methods of enzyme production and purification. Design and analysis of industrial-scale reactors employing soluble and immobilized enzymes. Prerequisite: Consent of the instructor.

**446. Biochemical Engineering Laboratory (3)** spring
Laboratory and pilot-scale experiments in fermentation and enzyme technology, tissue culture, and separations techniques. Prerequisites: ChE 341 and ChE 444 or ChE 342 previously or concurrently.

**448. Topics in Biochemical Engineering (3)** spring, every other year
Analysis, discussion, and review of current literature for a topical area of biotechnology. Course may be repeated for credit with the consent of the instructor. Prerequisite: Consent of the instructor.

**450. Special Topics (1-12)**
An intensive study of some field of chemical engineering not covered in the more general courses. Credit above three hours is granted only when different material is covered.

**451. Problems in Research (1)**
Study and discussion of optimal planning of experiments and analysis of experimental data. Discussion of more common and more difficult techniques in the execution of chemical engineering research.

**455. Seminar (1-3)**
Critical discussion of recent advances in chemical engineering. Credit above one hour is granted only when different material is covered.

**460. Chemical Engineering Project (1-6)**
An intensive study of one or more areas of chemical engineering, with emphasis on engineering design and applications. A written report is required. May be repeated for credit.

**461. Mathematical Methods in Chemical Engineering I (3)**
Application of ordinary and partial differential equations to the solution of chemical engineering problems with emphasis on chemical reactions and transport processes as they occur in industrial chemical processing. Applications of solution in series, separation of variables, and integral transforms. Prerequisite: Math 322. Caram

**464. Numerical Methods in Engineering (3)**
Survey of the principal numerical algorithms for: (1) functional approximation, (2) linear and nonlinear algebraic equations, (3) initial and boundary-value ordinary differential equations and (4) elliptic, hyperbolic and parabolic partial differential equations. Analysis of the computational characteristics of numerical algorithms, including algorithm structure, accuracy, convergence, stability and the effect of computer characteristics, e.g., the machine epsilon and dynamic range. Applications of mathematical software in science and engineering. Schiesser

**470. Cryogenic Engineering (3)**
Liquefaction and separation of gases, physical and chemical principles. Low temperature thermometry. Insulation. Properties of fluids and of structural materials. The behavior of helium. Ultra-low temperature phenomena and theories. Wenzel

**471. Low-Temperature Processes (3)**
The problems and design of plants operating in the cryogenic temperature range. Refrigeration demands. Distillation and heat exchange at low temperatures. Analysis of processes for thermodynamic and operating efficiency. Problems of safety, non-steady state behavior and control. Wenzel

**480. Research (3)**
Investigation of a problem in chemical engineering.

**481. Research (3)**
Continuation of ChE 480.

**482. (Chem 482, Mat 482) Engineering Behavior of Polymers (3)**
A treatment of the mechanical behavior of polymers. Characterization of experimentally observed viscoelastic response of polymeric solids with the aid of mechanical model analogs. Topics include time-temperature superposition, experimental characterization of large deformation and fracture processes, polymer adhesion, and the effects of fillers, plasticizers, moisture and aging on mechanical behavior.

**483. (Chem 483) Emulsion Polymers (3)** fall
Examination of fundamental concepts important in the manufacture, characterization, and application of polymer latexes. Topics to be covered will include colloidal stability, polymerization mechanisms and kinetics, reactor design, characterization of particle surfaces, latex rheology, morphology considerations, polymerization with functional groups, film formation and various application problems. El-Aasser, Vanderhoff, Klein

**484. (Chem 484) Crystalline Polymers (3)**
An in-depth treatment of the morphology and behavior of both polymer single crystals and bulk crystallized systems. Emphasis is placed on the relationship between basic crystal physics, thermal and annealing history, orientation and resulting properties. A detailed discussion of the thermodynamics and kinetics of transition phenomena and a brief treatment of hydrodynamic properties and their relationship to crystallization and processing properties. Prerequisite: ChE 392 or ChE 393 or equivalent.

**485. (Chem 485, MAT 485) Polymers Blends and Composites (3)**
An intensive study of the synthesis, morphology, and mechanical behavior of polymer blends and composites. Mechanical blends, block and graft copolymers, interpenetrating polymer networks, polymer impregnated concrete, and fiber and particulate reinforced polymers are emphasized. Prerequisite: any introductory course in polymers. Sperling

**486. Polymer Processing (3)**
Application of fundamental principles of mechanics, fluid dynamics and heat transfer to the analysis of a wide variety of polymer flow processes. A brief survey of the rheological behavior of polymers is also included. Topics include pressurization, pumping, die forming, calendering, coating, molding, fiber spinning and elastic phenomena. Prerequisite: ChE 392 or equivalent. Silebi

**492. (Chem 492) Topics in Polymer Science (3)**
Intensive study of topic selected from areas of current research interest such as morphology and mechanical behavior, thermodynamics and kinetics of crystallization, new analytical techniques, molecular weight distribution, non-Newtonian flow behavior, second-order transition phenomena, novel polymer structures. Credit above three hours is granted only when different material is covered. Prerequisite: Chem 392 or equivalent.

# Chemistry

**Professors.** Henry Leidheiser, Jr., Ph.D. (Virginia), *chairperson;* Jack A. Alhadeff, Ph.D. (Oregon Medical School); G. Doyle Daves, Ph.D. (M.I.T.); Ned D. Heindel, Ph.D. (Delaware), *Howard S. Bunn Professor of Chemistry and director, Center for Health Sciences;* Kamel Klier, Ph.D. (Czechoslovak Academy of Science, Prague), *University Professor of Chemistry;* Charles S. Kraihanzel, Ph.D. (Wisconsin); John W. Larsen, Ph.D. (Purdue); Roland W. Lovejoy, Ph.D. (Washington State); Joseph R. Merkel, Ph.D. (Maryland); Fortunato J. Micale, Ph.D. (Lehigh); William E. Ohnesorge, Ph.D. (M.I.T.); Steven L. Regen, Ph.D. (M.I.T.); Keith J. Schray, Ph.D. (Penn State); Gary W. Simmons, Ph.D. (Virginia), *director, Center for Surface and Coatings Research;* Donald M. Smyth, Ph.D. (M.I.T.), *director, Materials Research Center;* James E. Sturm, Ph.D. (Notre Dame); John W. Vanderhoff, Ph.D. (Buffalo), *director, Emulsion Polymers Institute, and associate director, Center for Surface and Coatings Research;* Thomas E. Young, Ph.D. (Illinois).
**Associate professors.** Michael J. Behe, Ph.D. (Pennsylvania); Daniel Zeroka, Ph.D. (Pennsylvania).
**Assistant professors.** Natalie Foster, Ph.D. (Lehigh); Leonard E. Klebanoff, Ph.D. (California-Berkeley); Linda J. LoweKrentz, Ph.D. (Northwestern); James E. Roberts, Ph.D. (Northwestern).
**Adjunct and active emeritus professors.** David W. Dwight, Ph.D. (Rensselaer); Robert Eischens, Ph.D. (Northwestern); Frederick M. Fowkes, Ph.D. (Chicago); Joseph J. Pronok, M.D. (Jefferson); Henry Yue, Ph.D. (Pittsburgh); Albert C. Zettlemoyer, Ph.D. (M.I.T.).

Chemistry is a versatile subject area and the pursuit of a career in chemistry can be a most intellectually satisfying experience. No other basic science touches and shapes as many aspects of modern society as does chemistry. From soft contact lenses and synthetic blood to longer-lasting paint and alternative fuel sources, the study of chemistry has provided the solutions to complex problems and has improved the quality of all phases of human life.

That chemists at all levels of education find a market for their skills and knowledge in every employment area is further demonstration of the breadth of the science of chemistry. Chemists provide the technical backbone for the manufacturing industries (pharmaceuticals, plastics, paper, electronics, agriculture), for service industries (clinical and forensic laboratories, academe, environmental protection, information science) and for governmental positions in regulatory agencies and in science policy analysis. Many chemists are also employed in non-traditional areas—patent law, insurance underwriting, sales, product management, journalism, and even banking.

The alluring challenge of chemistry inspires many bachelor degree holders to study for an advanced degree so that undergraduate preparation in chemistry enables future study within the discipline of chemistry and in other areas as well. Chemistry or biochemistry is the strongest preparation for graduate studies or professional school in the health-related disciplines (medicine, pharmacology, biochemistry) as well as for other science programs (materials science, polymers, environmental studies, mineralogy).

The study of chemistry opens doors to satisfying careers, to a stimulating view of the world, and to a professional life in which one's natural tendency to ask "why" can lead to personally rewarding endeavors.

The undergraduate curriculum in chemistry contains many of the prerequisites for biology, geological sciences, metallurgy, physics, and chemical engineering, so that students can normally transfer with no loss of credits at least through the sophomore year.

Chemistry students have the opportunity to design their undergraduate curricula for specialization in a variety of fields:

**health-related chemistry** (including premedical students)
suggested biology electives: 21, 22, 28, 220, 235, 327, 353, 367.
suggested chemistry electives: 336, 371, 372, 377, 378.

**materials chemistry** (polymers, solid state, surfaces)
suggested physics electives: 31, 363.
suggested chemistry electives: 312, 388, 392, 393, 394, 395, 396.

**environmental chemistry**
suggested biology electives: 21, 22, 135, 306, 309, 311.
suggested chemical engineering electives: 320, 321.
suggested chemistry electives: 303, 395.
suggested civil engineering elective: 374.

**geochemistry**
suggested geology electives: 21, 133, 333, 334, 336, 352, 372.
suggested chemistry electives: 303, 337, 396.

**chemistry management**
suggested accounting electives: 51, 52, 324.
suggested law elective: 201.
suggested management electives: 269, 270, 302, 321 or 333.
suggested economics electives: 105, 119, 145, 229.
suggested marketing electives: 211, 312.
suggested finance electives: 225, 330.

Certain of the above courses can be used to waive required graduate courses for the M.B.A. at Lehigh.

## *The Five-Year Program*

Five-year programs are available for students to receive bachelor of science or bachelor of arts degrees and the master of science degree in several fields of chemistry (inorganic, organic, analytical, physical chemistry, polymers or biochemistry). Interested students should consult with the assistant department chairman about this at least one year before graduation.

## B.S. and B.A. Degrees in Chemistry

The Department of Chemistry, now part of the College of Arts and Science, offers B.S. Chemistry programs in both the College of Arts and Science and the College of Engineering and Applied Science. In addition, the department offers a B.A. chemistry program in the College of Arts and Science. The B.S. chemistry programs in the two colleges are identical in their chemistry and collateral science requirements and are pre-professional in nature. Students planning to attend graduate school in chemistry or an allied science should elect the B.S. program in whichever college they have been admitted. The B.A. program in the College of Arts and Science is not a pre-professional program and may be elected by students who do not plan to do graduate work in chemistry or allied science but wish a stronger background in chemistry than is provided in the Chemistry Minor program. The B.A. program also affords a useful tie-in with health-related chemistry, environmental chemistry, geochemistry or chemistry management options (see above). Students may transfer from the B.S. to B.A. programs or vice-versa late in the junior year,

since basic requirements are the same for the two. Students who are in the B.A. program and make a late decision to attend graduate school in chemistry or allied science will have minimal chemistry preparation for this by electing Chemistry 307, Advanced Inorganic Chemistry. Students planning to major in any department program must be aware of the department's restrictive Modern Foreign Language requirement (see subsequently).

## *Bachelor of Science Degree in Chemistry— College of Engineering and Applied Science*

**freshman year** (see page 37) (30-31 credit hours)
Note: It is recommended that, where possible, students planning to major in chemistry take Chemistry 21/22 in the fall semester and Chemistry 31 in the spring semester of the freshman year. For such students the General Studies elective in the spring semester is displaced to a subsequent semester.

**sophomore year, first semester** (16 credit hours)

| | |
|---|---|
| Chem 51 | Organic Chemistry I (3) |
| Chem 53 | Organic Chemistry Laboratory I (1) |
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| | modern foreign language requirement (3)* |

*Chem. 31 Chemical Equilibria will displace this modern foreign language requirement to a subsequent semester if Chem. 31 was not taken in the freshman year.

**sophomore year, second semester** (16 credit hours)

| | |
|---|---|
| Chem 52 | Organic Chemistry II (3) |
| Chem 58 | Organic Chemistry Laboratory II (1) |
| Chem 187 | Physical Chemistry I (3) |
| Math 205 | Linear Methods (3) |
| | modern foreign language requirement (3) |
| | general studies requirement (3) |

**junior year, first semester** (16 credit hours)

| | |
|---|---|
| Chem 192 | Physical Chemistry Laboratory (2) |
| Chem 234 | Analytical Chemistry Laboratory (1) |
| Chem 332 | Analytical Chemistry (3) |
| Chem 341 | Chemical Physics and Bonding (4) |
| Chem 205 | Representative Elements (2) |
| Eco 1 | Economics (4) |

**junior year, second semester** (17 credit hours)

| | |
|---|---|
| Chem 353 | Organic Analysis Laboratory (3) |
| Chem 307 | Advanced Inorganic Chem. (3) |
| Chem 201 | Technical Writing (3) |
| | general studies requirement (3) |
| | free electives (6) |

**senior year, first semester** (14 credit hours)

| | |
|---|---|
| Chem 308 | Advanced Chem. Analysis (2) |
| | advanced chemistry elective (3) |
| | general studies requirement (3) |
| | free electives (6) |

**senior year, second semester** (15 credit hours)

| | |
|---|---|
| | advanced chemistry elective (3)* |
| | free electives (12) |

*This becomes a free elective if the advanced chemistry elective requirement was taken in the fall of the senior year.

## *Advanced Chemistry Elective Requirement*

One 3-credit course selected from the following:

| | |
|---|---|
| Chem 358 | Advanced Organic Chemistry |
| Chem 371 | Elements of Biochemistry I |
| Chem 376 | Advanced Chemistry Research Lab |
| Chem 381 | Radiation and Structure |
| Chem 382 | Spectroscopy and Photochemical Kinetics |
| Chem 392 | Introduction to Polymer Science |
| Chem 393 | Physical Polymer Science |
| Chem 394 | Organic Polymer Science |
| Phys 363 | Physics of Solids |

Students are encouraged to take any second course that sequences the first by means of a free elective.

**Summary**
Total required chemistry hours — 44
Total required physics, mathematics, computer hours — 28
Total required college distribution hours —25*
Unrestricted elective hours — 27
Program total hour requirement is 124

*The department modern foreign language requirement would normally meet college distribution requirements and be included in the 25 hours. In the event that this is not the case, then unrestricted elective hours will have to be used to meet this modern foreign language requirement.

## *Bachelor of Science Degree in Chemistry— College of Arts and Science*

I. College and University Requirements —37 hours
   a. English 1 — 3 hours
   b. Arts and Science 1 — 1 hour
   c. English 2, 4, 6, 8 or 10 — 3 hours
   d. Non-science electives — 30 hours to be broadly distributed in fields of thought other than natural science and mathematics, including at least 12 hours each in humanities and social sciences and including the department modern foreign language requirement.
II. Collateral Science Requirements — 28 hours
   a. Physics 11, 12, 21, 22 — 10 hours
   b. Mathematics 21, 22, 23, 205 — 15 hours
   c. Computer Science 11 or Engineering 1 — 3 hours
III. Required Chemistry Courses — 44 hours
   a. Introductory Chemistry — Chemistry 21, 22, 31 — 8 hours
   b. Organic Chemistry — Chemistry 51, 52, 53 58, 353 —11 hours
   c. Inorganic Chemistry — Chemistry 205, 307 — 5 hours
   d. Physical Chemistry —Chemistry 187, 192, 341 — 9 hours
   e. Analytical Chemistry —Chemistry 234, 332, 338 —6 hours
   f. Technical Writing —Chemistry 201 — 2 hours (W-I course)
   g. Advanced Chemistry Elective — 3 hours

See list of choices for this Advanced Chemistry Elective requirement under the revised B.S. chemistry program —Engineering College.

IV. Free Electives — 12 hours (based on 121 total hours)

## *Model Pattern Roster*

**freshman year, first semester** (16 credit hours)

| | |
|---|---|
| Arts and Sc 1 | Choices and Decisions (1) |
| Engl 1 | Composition and Literature (3) |
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |
| Math 21 | Analytic Geometry and Calculus I (4) |
| Comp Sci 11 or Engineering 1 | Computer Programming (3) |

**freshman year, second semester** (15 credit hours)

| | |
|---|---|
| Engl 2 | Composition and Literature (3)* |
| Phys 11, 12 | Introductory Physics I and Laboratory (5) |
| Math 22 | Analytic Geometry and Calculus II (4) |
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) |

*Engl 4, 6, 8 or 10 may replace Engl 2.

**sophomore year, first semester** (16 credit hours)

| | |
|---|---|
| Chem 51 | Organic Chemistry I (3) |
| Chem 53 | Organic Chemistry Lab I (1) |
| Phys 21 | Introductory Phys. II (4) |
| Phys 22 | Introductory Phys. II Lab (I) |

Math 23 Analytic Geometry and Calculus III (4)
modern foreign language requirement (3)*

*Chem 31 Chemical Equilibria will displace this modern foreign language requirement to a subsequent semester if Chem 31 was not taken in the freshman year.

**sophomore year, second semester** (16 credit hours)
Chem 52 Organic Chemistry II (3)
Chem 58 Organic Chemistry Lab II (1)
Chem 187 Physical Chem. I (3)
Math 205 Linear Methods (3)
modern foreign language requirement (3)
distribution requirement (3)

**junior year, first semester** (15 credit hours)
Chem 192 Physical Chemistry Lab (2)
Chem 234 Analytical Chemistry Lab (1)
Chem 332 Analytical Chemistry (3)
Chem 341 Chem. Physics and Bonding (4)
Chem 205 Representative Elements (2)
distribution requirement (3)

**junior year, second semester** (14 credit hours)
Chem 353 Organic Analysis Laboratory (3)
Chem 307 Advanced Inorganic Chem. (3)
Chem 201 Technical Writing (2)
distribution requirements — free electives (6)

**senior year, first semester** (14 credit hours)
Chem 338 Advanced Chem. Analysis (2)
advanced chemistry elective (3)
distribution requirements — free electives (9)

**senior year, second semester** (15 credit hours)
advanced chemistry elective (3)*
distribution requirements — free electives (12)

*This becomes a free elective if the advanced chemistry elective was taken in the fall semester of the senior year.

## *Bachelor of Arts Degree in Chemistry— College of Arts and Science*

I. College and University Requirements — 7 hours
a. English 1 — 3 hours
b. Arts and Science 1 — 1 hour
c. English 2, 4, 6, 8 or 10 — 3 hours

II. Distribution Requirements (other than above) — 36 hours minimum
a. Foreign language — 6-8 hours
b. Life Sciences — 3-4 hours
c. Social Sciences — 12-13 hours
d. Humanities — 12 hours
e. Performing and Studio Arts — 3 hours

III. Collateral Science Requirements — 28 hours
a. Physics 11, 12, 21, 22 — 10 hours
b. Mathematics 21, 22, 23, 205 — 15 hours
c. Computer Science 11 or Engineering 1 — 3 hours

IV. Required Chemistry Courses — 33 hours
a. Introductory Chemistry — Chemistry 21, 22, 31 — 8 hours
b. Organic Chemistry — Chemistry 51, 52, 53, 58 — 8 hours
c. Inorganic Chemistry — Chemistry 205 — 2 hours
d. Physical Chemistry — Chemistry 187, 192, 341 — 9 hours
e. Analytical Chemistry — Chemistry 234, 332 — 4 hours
f. Technical Writing — Chemistry 201 — 2 hours

V. Free Electives — 17 hours maximum (based on 121 total hours)

## *Model Pattern Roster*

**freshman year, first semester** (16 credit hours)
Arts and Sc 1 Choices and Decisions (1)
Engl 1 Composition and Literature (3)
Chem 21, 22 Introductory Chemical Principles and Laboratory (5)
Math 21 Analytic Geometry and Calculus I (4)
Comp Sci 11 or Engineering 1 Computer Programming (3)

**freshman year, second semester** (15 credit hours)
Engl 2, 4, 6, 8 or 10 Composition and literature (fiction, poetry, drama, film) (3)
Phys 11, 12 Introductory Physics I and Laboratory (5)
Chem 31 Chemical Equilibria in Aqueous Systems (3)
Math 22 Analytic Geometry and Calculus II (4)

**sophomore year, first semester** (16-17 credit hours)
Chem 51 Organic Chemistry I (3)
Chem 53 Organic Chemistry Lab I (1)
Phys 21 Introductory Phys. II (4)
Phys 22 Introductory Phys. Lab II (1)
Math 23 Analytic Geometry and Calculus III (4)
modern foreign language requirement (3-4)*

*If Chem 31 was not taken in the freshman year, this course must be taken first semester sophomore year and will displace this modern foreign language requirement to a subsequent semester.

**sophomore year, second semester** (16-17 credit hours)
Chem 52 Organic Chemistry II (3)
Chem 58 Organic Chemistry Lab II (1)
Chem 187 Physical Chemistry I (3)
Math 205 Linear Methods (3)
modern foreign language requirement (3-4)
distribution requirement (3)

**junior year, first semester** (15 credit hours)
Chem 192 Physical Chemistry Lab (2)
Chem 234 Analytical Chemistry Lab (1)
Chem 332 Analytical Chemistry (3)
Chem 341 Chem. Physics and Bonding (4)
Chem 205 Representative Elements (2)
distribution requirement (3)

**junior year, second semester** (14 credit hours)
Chem 201 Technical Writing (2) (W-1 course)
distribution requirements and free electives (12)

**senior year, first semester** (15 credit hours)
distribution requirements and free electives (15)

**senior year, second semester** (15 credit hours)
distribution requirements and free electives (15)

**Chemistry Department Modern Foreign Language Requirement—B.S.and B.A. Degrees—Chemistry/Biochemistry**

The Department of Chemistry requires each student to demonstrate competence in a modern foreign language which is useful in science. These are French, German, Russian and Japanese. Satisfactory completion of two semesters of study (6-8 cr) at the introductory level at Lehigh for the first three languages will meet this requirement. Instruction in Japanese is not given at Lehigh; however, demonstrated competence to read this language will be accepted to meet this requirement.

Students who can demonstrate reading competence equivalent to one or two semesters of introductory French, German or Russian at Lehigh can meet the departmental language requirement with less than 6-8 credits. In this case, other approved general studies or distribution courses must be taken to meet those requirements.

## Minor in Chemistry

A minor in chemistry may be achieved by completing the following requirements:

| | |
|---|---|
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) |
| Chem 51 | Organic Chemistry I (3) |
| Chem 53 | Organic Chemistry Laboratory I (1) |
| Chem 187 | Physical Chemistry I (3) |
| Chem 192 | Physical Chemistry Laboratory (2) |
| Chem 332 | Analytical Chemistry (3) |

Total Credits—15

Necessary pre- or co-requisites for the above would be Chem 21 and 22, Math 21 and Physics 11.

Students who wish to minor in chemistry but whose major program requires any of the above courses may achieve the minor with substitutions approved by the department chairman.

## B.S. in Biochemistry

A B.S. Biochemistry major is offered in both the College of Engineering and Applied Science and the College of Arts and Science. The chemistry, biochemistry and collateral science requirements are the same for both programs. These programs are based on the standard freshman year and the normal sophomore year of the B.S. chemistry programs in either college.

Concentration in biochemistry courses takes place in the junior and senior years at the expense of some electives and of two courses in the normal chemistry curriculum. Consequently, graduates of this program are prepared to go into graduate work in several fields—medicine, biochemistry, chemistry, biophysics, and biology.

This curriculum requires 126 semester-hour credits. Students are expected to meet this total hour requirement unless there are exceptional circumstances.

### *Bachelor of Science Degree in Biochemistry— College of Engineering and Applied Science*

**freshman year** (see page 37 of current catalog) (30 credit hours)
Note: It is recommended that, where possible, students planning to major in chemistry take Chemistry 21/22 in the fall semester and Chemistry 31 in the spring semester of the freshman year. For such students, the General Studies elective in the spring semester is displaced to a subsequent semester.

**sophomore year, first semester** (16 credit hours)

| | |
|---|---|
| Chem 51 | Organic Chemistry I (3) |
| Chem 53 | Organic Chemistry Lab I (1) |
| Phys 21 | Intro. Physics II (4) |
| Phys 22 | Intro. Physics Lab II (1) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| | modern foreign language requirement (3)* |

*Chem 31, Chemical Equilibria, will displace this modern foreign language requirement to a subsequent semester if Chem 31 was not taken in the freshman year.

**sophomore year, second semester** (16 credit hours)

| | |
|---|---|
| Chem 52 | Organic Chemistry II (3) |
| Chem 58 | Organic Chemistry Lab II (1) |
| Chem 187 | Physical Chemistry I (3) |
| Math 205 | Linear Methods (3) |
| | modern foreign language requirement (3) |
| | biology elective (3) |

**junior year, first semester** (17 credit hours)

| | |
|---|---|
| Chem 234 | Analytical Chemistry Lab (1) |
| Chem 332 | Analytical Chemistry (3) |
| Chem 371 | Elem. of Biochemistry I (3) |
| Chem 377 | Biochem. Lab (3) |
| Eco 1 | Economics (4) |
| | general studies requirement (3) |

**junior year, second semester** (17 credit hours)

| | |
|---|---|
| Chem 372 | Elem. of Biochemistry II (3) |
| Chem 353 | Organic Analysis Lab (3) |
| Chem 201 | Technical Writing (2) |
| | general studies requirement (3) |
| | free electives (6) |

**senior year, first semester** (15 credit hours)

| | |
|---|---|
| Chem 341 | Chemical Physics and Bonding (4) |
| Chem 192 | Physical Chemistry Lab (2) |
| | biochem, biophys or biology elective (3) |
| | general studies requirement (3) |
| | free elective (3) |

**senior year, second semester** (15 credit hours)

| | |
|---|---|
| Chem 307 | Adv. Inorganic Chem (3) |
| | biochem, biophys or biology elective (3) |
| | free electives (9) |

**Summary**
Total required chemistry hours — 37
Total required biochemistry and biochem/biophys/biology hours —18*
Total required physics, mathematics, computer hours — 28
Total required college distribution hours — 25**
Unrestricted elective hours — 18
Program total hours requirement is 126.

*The nine credit hours of biochemistry/biophysics/biology electives are chosen with the approval of the adviser.

**The department modern foreign language requirement would normally meet college distribution requirements and be included in the 25 hours. In the event that this is not the case, then unrestricted elective hours will have to be used to meet this modern language requirement.

### *Bachelor of Science Degree in Biochemistry— College of Arts and Science*

I. College and University Requirements — 37 hours
   a. English 1 — 3 hours
   b. Arts and Science 1 — 1 hour
   c. English 2, 4, 6, 8 or 10 — 3 hours
   d. Non-science electives — 30 hours to be broadly distributed in fields of thought other than natural science and mathematics, including at least 12 hours each in humanities and social sciences and including the department modern foreign language requirement.
II. Collateral Science Requirements — 28 hours
   a. Physics 11, 12, 21, 22 — 10 hours
   b. Mathematics 21, 22, 23, 205 — 15 hours
   c. Computer Science 11 or Engineering 1 — 3 hours
III. Required Chemistry Courses — 37 hours
   a. Introductory Chemistry — Chemistry 21, 22, 31 — 8 hours
   b. Organic Chemistry — Chemistry 51, 52, 53 58, 353 —11 hours
   c. Inorganic Chemistry — Chemistry 307 — 3 hours
   d. Physical Chemistry — Chemistry 187, 192, 341 — 9 hours
   e. Analytical Chemistry — Chemistry 234, 332 — 4 hours
   f. Technical Writing — Chemistry 201 — 2 hours (W-I course)
IV. Required Biochemistry Courses and Biochemistry, Biophysics and Biology Electives — 18 hours
   a. Biochemistry 371, 372, 377 — 9 hours
   b. Biochemistry, Biophysics, Biology Electives — 9 hours minimum*
V. Free Electives — 1 hour (based on 121 total hours)

*The nine credit hours of biochemistry/biophysics/biology electives are chosen with the approval of the adviser.

### *Model Pattern Roster*

**Freshman and Sophomore Years**
See B.S. Biochemistry — College of Engineering and Applied Science

**junior year, first semester** (16 credit hours)

| | |
|---|---|
| Chem 234 | Analytical Chemistry Lab (1) |
| Chem 332 | Analytical Chemistry (3) |
| Chem 371 | Elem. of Biochemistry I (3) |
| Chem 377 | Biochem. Lab (3) |
| | distribution requirements (6) |

**junior year, second semester** (14 credit hours)

| | |
|---|---|
| Chem 372 | Elem. of Biochemistry II (3) |
| Chem 353 | Organic Analysis Lab (3) |
| Chem 201 | Technical Writing (2) |
| | distribution requirements and free electives (6) |

**senior year, first semester** (15 credit hours)

| | |
|---|---|
| Chem 341 | Chemical Physics and Bonding (4) |
| Chem 192 | Physical Chemistry Lab (2) |
| | biochem, biophys or biology elective (3) |
| | distribution requirements and free electives (6) |

**second year, second semester** (14 credit hours)

| | |
|---|---|
| Chem 307 | Advanced Inorganic Chem (3) |
| | biochem, biophys or biology elective (3) |
| | distribution requirements and free electives (8) |

## Undergraduate Courses in Chemistry

**21. Introductory Chemical Principles (4)** fall-spring
An introduction to important topics in chemistry. These include atomic structure, bonding in inorganic and organic compounds, states of matter, chemical equilibrium, acid-base theories and electrochemistry. Prerequisite: Math 21, 31 or 41 previously or concurrently. Three lectures, one recitation.

**22. Chemical Principles Laboratory (1)** fall-spring
A laboratory course to be taken concurrently with Chem 21. One three-hour laboratory period per week.

**31. Chemical Equilibria in Aqueous Systems (3)** fall-spring
A study of the theoretical basis and practical applications of equilibria in aqueous solutions, including acid-base, precipitation-solubility, metal-ligand, oxidation-reduction and distribution equilibria. Introduction to chemical thermodynamics, spectrophotometry, potentiometry and chromatography. The laboratory work emphasizes the qualitative and quantitative analysis of equilibria in aqueous media. Prerequisite: Chem 21, Math 21; Phys 11 previously or concurrently. Two lectures and one three-hour laboratory period.

**51. Organic Chemistry I (3)** fall
Systematic survey of the typical compounds of carbon, their classification, and general relations; study of synthetic reactions. Prerequisite: Chem 21.

**52. Organic Chemistry II (3)** spring
Continuation of Chem 51. Prerequisite: Chem 51.

**53. Organic Chemistry Laboratory I (1)** fall
Preparation of pure organic compounds. Modern techniques of characterization. Prerequisite: Chem 31; Chem 51 previously or concurrently.

**58. Organic Chemistry Laboratory II (1)** spring
Continuation of Organic Chemistry Laboratory I. Prerequisite: Chem 53 previously; Chem 52 previously or concurrently.

**187. Physical Chemistry I (3)** spring
Development of the principles of thermodynamics and their application to systems in which composition is of major concern: solutions, chemical and phase equilibria. Elements of chemical reaction kinetics. Prerequisite: Chem 31 or Met 210, and Math 21 or 41 previously or concurrently.

**189. Physical Chemistry II (3)** fall
A continuation of Chemistry187. Kinetic theory of gases, statistical thermodynamics, electrolytes in solution, electrochemistry, corrosion, colloid and surface chemistry and the solid state. Prerequisites: Chem 187, Math 23, Phys 21.

**192. Physical Chemistry Laboratory (2)**
Laboratory studies that illustrate the various fields of study in experimental physical chemistry. Prerequisite: Chem 187.

**193. (Biol 191, Geol 191) Environmental Science Seminar (1)** fall and spring
Current developments in environmental science presented by students and discussed in seminar style. An interdisciplinary approach linking biological, geological, and chemical principles as they relate to causes and controls of environmental problems. May be taken more than once for credit. Prerequisite: sophomore standing.

**194. Physical Chemistry for Biological Sciences (3)** fall
The principles and applications of physical chemical concepts to systems of biological interest, including the gas laws, thermodynamics of metabolic reactions, colligative properties, electrochemical equilibria, reaction kinetics and enzyme catalysis, and transport of macromolecules and viruses. Prerequisite: Chem 21.

**201. Technical Writing (2)**
Principal types of written communications used by professional chemists including informative abstracts, research proposals, progress reports, executive summaries for nonchemist decision makers and proper written experimental procedures, tables, schemes and figures. Prerequisite: junior standing in Chemistry major or consent of the department chairperson.

**205. Representative Elements (2)** fall
The chemical and physical properties of the representative elements and their hydrides, oxides and halides. Material will include pertinent aspects of acid-base theories, non-aqueous solvents, the diagonal relationships and inorganic polymers. Prerequisite: Chem 31.

**207. Metallic Elements (3)** fall
A systematic study of the inorganic chemistry of the metallic elements and their major compounds with emphasis on the properties and structures of solid materials. Grouping of elements with similar properties within the periodic table is stressed. Prerequisite: Chem 21. Smyth

**234. Analytical Chemistry Laboratory (1)** fall
Laboratory course: experiments coordinated with and illustrating methods and principles discussed in Chem 332. Ohnesorge

**250. Special Topics (1-3)**
Selected topics in chemistry. May be repeated for credit when different topics are offered.

**303. Nuclear and Radiochemistry (3)**
A broad survey of nuclear science with particular emphasis on aspects of importance to chemistry and biology. Elementary nuclear theory, production, separation, and identification of radioactive and stable isotopes; use of isotopes in the study of chemical and biological systems; radiological safety; nuclear engineering. Two lectures and one lecture-laboratory. Prerequisite: Chem 187 or Chem 194, or consent of the department chairperson. Sturm

**307. Advanced Inorganic Chemistry (3)** spring
Selected topics in inorganic chemistry. Descriptive chemistry of the representative elements; introduction to transition metal complexes and the theories of bonding in these substances; kinetics and mechanisms of transition metal complex reactions; selected aspects of organometallic chemistry; bioinorganic chemistry. Prerequisite: Chem 341.

**312. (ChE 312, Mat 312) Fundamentals of Corrosion (3)** fall
Corrosion phenomena and definitions. Electrochemical aspects including reaction mechanisms, thermodynamics, Pourbaix diagrams, kinetics of corrosion processes, polarization and passivity. Non-electrochemical corrosion including mechanisms, theories and

quantitative descriptions of atmospheric corrosion. Corrosion of metals under stress. Cathodic and anodic protection, coatings alloys, inhibitors, and passivators. Prerequisite: Met 210 or Chem 187. Leidheiser

**332. Analytical Chemistry (3)** fall
Theory and practice of chemical analysis. Principles of quantitative separations and determinations; theory and application of selected optical and electrical instruments in analytical chemistry; interpretation of numerical data, design of experiments, solute distribution in separation methods. Prerequisites: Chem 31 and 51. Ohnesorge

**336. Clinical Chemistry (3)** spring
Applications of analytical chemistry to clinical problems. Discussion of methods in common use and the biochemical-medical significance of the results. Prerequisites: Chem 332 and 52. Ohnesorge, Schray

**337. (Geol 337, Mat 333) X-ray Diffraction of Materials (3)** fall
Emphasis on materials characterization with computer-controlled powder diffractometers. Specific topics include x-ray spectroscopy, crystallographic notation, orientation of single crystals, preferred orientations in polycrystals, crystallite size measurement, phase identification, quantitative analysis of crystalline phases, and stress measurement. Applications in mineralogy, metallurgy, ceramics, microelectronics, polymers, and catalysts. Lectures and laboratory work. Prerequisite: consent of department chairperson. Lyman

**338. Advanced Chemical Analysis (2)** spring
A lecture-laboratory course in continuation of Chem 234 and 332 emphasis on spectrochemical, electroanalytical and chromatographic techniques. Prerequisites: Chem 234, 332.

**341. Chemical Physics and Bonding (4)** fall
Development of ideas relating to the nature of the chemical bond. Emphasis placed on the quantum chemistry of atoms and molecules. Statistical thermodynamics of gaseous and solid systems. Diffraction effects in crystalline solids. Properties of the liquid state. Macromolecules. Prerequisites: Chem 187, Math 205, Physics 21.

**350. Special Topics (1-3)**
Selected advanced topics in chemistry. May be repeated for credit when different topics are offered.

**353. Organic Analysis Laboratory (3)** spring
Identification of organic compounds as single components and mixtures. Application of combined chemical and spectral assay techniques. Use and interpretation of data from nuclear magnetic resonance, infrared, and mass spectroscopic examinations. Separation techniques for mixtures. Prerequisites: Chem 52 and 58.

**358. Advanced Organic Chemistry (3)** fall
The study of modern theories of reaction mechanisms and their applications to the problems of organic chemistry. Prerequisite: one year of organic chemistry. Young

**368. Advanced Organic Laboratory (2)**
The synthesis and study of organic compounds illustrating the important techniques and special pieces of apparatus commonly used in organic chemical research. Prerequisite: one year of organic chemistry and laboratory.

**371. (Biol 371) Elements of Biochemistry I (3)** fall
A general study of carbohydrates, proteins, lipids, nucleic acids, and other biological substances and their importance in life processes. Protein and enzyme chemistry are emphasized. Prerequisite: one year of organic chemistry.

**372. (Biol 372) Elements of Biochemistry II (3)** spring
Dynamic aspects of biochemistry: enzyme reactions including energetics, kinetics and mechanisms, metabolism of carbohydrates, lipids, proteins and nucleic acids, photosynthesis, electron transport mechanisms, coupled reactions, phosphorylations, and the synthesis of biological macromolecules. Prerequisite: Chem 371.

**375. Research Chemistry Laboratory (1-3)** fall-spring
An introduction to independent study or laboratory investigation under faculty guidance. Prerequisite: consent of department chairperson.

**376. Advanced Research Chemistry Laboratory (1-6)** fall-spring
Advanced independent study or laboratory investigation under faculty guidance after preliminary experience in Chem 375. Prerequisite: 3 credits of Chem 375.

**377. Biochemistry Laboratory (3)** fall
Laboratory studies of the properties of chemicals of biological origin and the influence of chemical and physical factors on these properties. Laboratory techniques used for the isolation and identification of biochemicals. Prerequisite: Chem 371, previously or concurrently. Merkel or Alhadeff

**378. Biochemical Preparations (1-3)** spring
A laboratory course involving the preparation or isolation, purification and identification of chemicals of biological origin. Prerequisites: Chem 377 and 372, previously or concurrently. Merkel or Alhadeff

**381. Radiation and Structure (3)** spring
Quantum chemistry and group theory applied to molecular orbital theory of bonding, structure, and spectroscopy. Study of selection rules for chemical and photochemical reactions. Prerequisites: Chem 341 and Math 205. Klier

**382. Spectroscopy and Photochemical Kinetics (3)** spring
Applications of electronic, infrared, and microwave spectroscopy to the study of molecular structure. Chemical consequences of intramolecular excitation; quantum efficiences and reaction mechanisms; pulse excitation and dynamics of elementary processes. Prerequisite: Chem 341. Lovejoy, Sturm

**385. Physical Chemistry of Printing Inks (3)** fall
Physical chemical mechanisms of printing processes; composition, dispersion processes for pigments rheology and printability of inks; color-matching; development of solventless inks and specialty inks. Prerequisite: Chem 187 or equivalent. Vanderhoff

**388. (ChE 388) Polymer Synthesis and Characterization Laboratory (3)** spring
Techniques include: free radical and condensation polymerization; molecular weight distribution by gel chromatography; crystallinity and order by differential scanning calorimetry; pyrolysis and gas chromatography; dynamic mechanical and dielectric behavior; morphology and microscopy; surface properties. Prerequisite: Chem 187, 189 or 341 and 51. El-Aasser

**392. (ChE 392) Introduction to Polymer Science (3)** spring
Introduction to concepts of polymer science. Kinetics and mechanisms of polarization; synthesis and processing of polymers, characterization. Relationship of molecular conformation, structure and morphology to physical and mechanical properties. Prerequisite: Chem 187 or equivalent. Sperling

**393. (ChE 393, Mat 343) Physical Polymer Science (3)** fall
Structural and physical aspects of polymers (organic, inorganic, natural). Molecular and atomic basis for polymer properties and behavior. Characteristics of glassy, crystalline and paracrystalline states (including visoelastic and relaxation behavior) for single and multicomponent systems. Thermodynamics and kinetics of transition phenomena. Structure, morphology and behavior. Prerequisite: one year of physical chemistry. Sperling

**394. (ChE 394) Organic Polymer Science I (3)** spring
Organic chemistry of synthetic high polymers. Polymer nomenclature, properties, and applications. Functionality and reactivity or monomers and polymers. Mechanism and kinetics of step-growth and chain-growth polymerization in homogenous and heterogenous media. Brief description of emulsion polymerization, ionic polymerization, and copolymerization. Prerequisite: one year of physical chemistry and one year of organic chemistry.

**395. Colloid and Surface Chemistry (3)** fall
Physical chemistry of everyday phenomena. Intermolecular forces and electrostatic phenomena a interfaces, boundary tensions and

films at interfaces, mass and charge transport in colloidal suspensions, electrostatic and London forces in disperse systems, gas adsorption and heterogeneous catalysis. Prerequisite: Chem 187 or equivalent. Fowkes, Micale

**396. (Mat 396) Chemistry of Nonmetallic Solids** (3) spring
Chemistry of ionic and electronic defects in nonmetallic solids and their influence on chemical and physical properties. Intrinsic and impurity controlled defects nonstoichiometric compounds, defect interactions. Properties to be discussed include: diffusion, sintering, ionic and electronic conductivity, solid-state reactions, and photoconductivity. Prerequisite: Chem 187 or Met 210 or equivalent. Smyth

## Graduate Programs in Chemistry

The department of chemistry offers graduate studies leading to several advanced degrees. These include master of science and doctor of philosophy degrees in chemistry, a doctor of arts in chemistry, master of science and doctor of philosophy degrees in physiological chemistry and a master of science in clinical chemistry. Master of science and doctor of philosophy degrees in chemistry may be obtained by study and research in the following areas of chemistry—analytical, biochemistry, inorganic, organic, physical and polymers. Additional information concerning the physiological chemistry and clinical chemistry programs may be obtained from Section IV of this catalog. The doctor of arts degree includes broad course work in many of the major subdisciplines of chemistry and requires two areas of specialization. A laboratory problem in chemistry (at the M.S. level) and a chemical education project (at the doctoral level) are required. A teaching internship (Chem 411) and an industrial externship are part of the degree program—a program which is particularly intended to upgrade college teachers presently employed in academia but not holding the doctorate.

The chemistry department also admits students to the master of science and doctor of philosophy degree programs in molecular biology and polymer science and engineering. These are interdisciplinary programs which are described in Section IV of this catalog and are *not* administered by the chemistry department. The following information on admissions, proficiency examinations and other policies applies to all of the programs listed above but not to the molecular biology and polymer science and engineering programs.

Admission to graduate study in chemistry assumes that a student has met, or is willing to meet though further study, minimum undergraduate requirements for a bachelor's degree in chemistry. This would include (beyond two semesters of introductory chemistry) two semesters of organic chemistry, two semesters of physical chemistry, two semesters of analytical chemistry and one semester of inorganic chemistry. A promising student whose degree is in a field related to chemistry (e.g., biology, chemical engineering) may be admitted to graduate study in chemistry provided that any deficiencies in basic chemistry preparation are made up in the first year of graduate study and noting that some of the courses required for this may not carry graduate credit.

The Chemistry Department will administer proficiency examinations in analytical, biochemistry, inorganic, organic and physical chemistry to all regular graduate students at the time of matriculation. Each student is required to take three examinations. Information regarding material to be covered on these examinations will be sent to each student several months in advance of matriculation. It is expected that each student will prepare diligently for these tests. A student who performs well on one or more of these tests has an opportunity to take advanced level and special topics courses at an earlier than normal time and may in fact begin graduate research during the first year. A Ph.D. candidate must show proficiency in three areas and an M.S. candidate in two areas within the first year in residence. A student who fails one or more of the proficiency examinations will meet with the department Graduate Advisory Committee to determine an appropriate course of action in light of the exam performance, projected major and degree aspiration. Two optional routes are available for demonstration of proficiency. (1) The student through self-study and auditing of appropriate courses may prepare for a retaking of a proficiency examination at the beginning of the second semester in residence. (2) Alternatively, the student may enroll in appropriate 300 or 400 level courses during the first year in residence. A grade of B− or better in an appropriate 300-400 level course will be considered equivalent to passing the proficiency examination in that area. Courses taken as a means of demonstrating proficiency will be acceptable on the M.S. or Ph.D. graduate program.

Work for the master's degree requires at least 30 credits—a minimum of 24 course credits and 6 credits of research (which may involve either a laboratory or literature research project). There are no required courses for the M.S., once proficiency has been established. The courses taken are those deemed appropriate for the student's area of concentration. There is a one credit seminar requirement for the M.S. Normally, work for the master's degree can be completed in 1½ calendar years.

Completion of a doctor of philosophy degree program normally requires a minimum of four years full-time work after entrance with a bachelor's degree. There are no specific course credit requirements for the Ph.D.; however, approved degree programs generally have at least 30 hours of course work (including any applied toward a master's degree) and 6 credits of research. Thus, the program consists of approximately one-third formal course work and two-thirds independent study and research. There is a foreign language requirement for the Ph.D. First year college proficiency in one of the four languages—French, German, Russian or Japanese—must be established on some basis. There is also a two credit seminar requirement. After Ph.D. proficiency has been established and the research advisor selected (this must be done by the end of the first year in residence), the major hurdles are the doctoral examinations (both written and oral) in the student's area of concentration which must be passed by the end of 2½ years of residence. If this hurdle is surmounted, the remaining time is spent completing (and ultimately defending) the thesis research under the guidance of the research adviser and the thesis committee.

Most of the chemistry facilities are housed in the 90,000-square-foot chemistry complex, first occupied in 1975. The seven-story Seeley G. Mudd Building affords laboratory space of modern design; the top three floors are devoted to research laboratories. Most of the research laboratories in the adjacent Sinclair Laboratory are assigned to chemistry professors who specialize in research in surface and colloid chemistry.

Physiological chemistry research is located in Chandler-Ullmann Hall and in the Seeley G. Mudd Building. Solid-state chemical research is located in the Sherman Fairchild Laboratory, in Coxe Laboratory, in the Seeley G. Mudd Building, and in Sinclair Laboratory. Polymer chemistry research laboratories are located in Coxe Laboratory, Sinclair Laboratory, and the Seeley G. Mudd Building.

### *Current Research Projects*

Current research projects of interest are listed below.

**Analytical chemistry.** Gas chromatograph-mass spectroscopy of trace organics, electrochemical reduction and oxidation mechanisms of organic compounds, clinical-biomedical applications, mechanisms of electrode processes, adsorption; redox behavior of transition metal complexes; luminescence of metal-ion complexes in organized media.

**Biochemistry.** Production, isolation and characterization of proteolytic enzymes of marine bacteria; determination of the amino acid specificity of bacterial proteases; mechanism of action of proteolytic enzymes; collagenolytic enzymes of bacteria; factors affecting collagenase production of bacteria and tissues in culture; characterization of lysosomal glycosidases and glycosyltransferases; functional role of carbohydrates in glycoproteins; abnormal glycoprotein metabolism in human diseases; synthesis and characterization of novel polynucleotides; sequence dependence of the B-Z transition of DNA; non-isotopic immunoassays; protein surface binding phenomena; development of *in vitro* evaluation techniques for prescreening candidate pharmaceuticals; structural dynamics and molecular associations of biologically significant molecules; relaxation phenomena in NMR and the development of contrast enhancement agents for medical imaging.

**Inorganic chemistry.** Synthesis, characterization and chemistry of transition metal organometallic complexes with alkyl, carbonyl, nitroso, dinitrogen, dioxygen and phosphine ligands. Addition reactions of the benzene-Cu(I) complex. Applications of molecular

mechanics and molecular orbital theories in studies of inorganic and organic derivatives of the representative elements and transition metals. Synthesis of solid catalysts including oxides, sulfides, zeolites and supported metals. Solid state chemistry of dielectric and electro-optic oxides. Defect chemistry and non-stoichiometry of transition metal oxides.

**Organic chemistry.** Synthesis of medicinal agents, correlation of molecular structure with pharmacological behavior; chemical models for biochemical reactions; biosyntheses involving indole intermediates; mechanism of formation and structure of melánin; synthesis of new heterocyclic systems; mechanisms of phosphoglucose isomerase and aldolase; synthesis and phosphoryl transfer of phosphate esters of biological interest; radio pharmaceuticals; organic reactions in molten salts.

**Physical chemistry.** Colloid and surface research include latexes, surface coatings, colloidal stability, adhesion, surface properties of catalysts relating powder flow to their surface chemistry, water at surfaces, fundamental studies of gas-solid surface reactions, printing inks, chemical reactions in small confined volumes, microcalorimetric and FTIR spectrometric studies of Lewis acid-base interactions at interfaces and surface spectroscopy. Solid-state chemistry includes studies of point defects in oxides and oxide growth. Other fields include photochemical dynamics, applications of very high resolution infrared spectroscopy to analytical problems of vibration-rotation lines, nuclear magnetic resonance and applications of quantum mechanics and statistical mechanics to problems of chemical interest. Role of ionic bonding in the macromolecular structure of coals. Stabilities of homoconjugated carbocations. Thermodynamics of formation of organic intermediates. Coal chemistry. Electrostatics of non-aqueous systems. Single crystal vibrational and electron surface spectroscopy; structure-function relationships in catalysis; intrazeolitic transition metal ion complexes-spectroscopy, structure and reactivity; kinetics of heterogenously catalyzed reactions.

**Polymer chemistry.** Synthesis, structure, conformation and properties of high polymers; techniques and kinetics of emulsion polymerization and film formation; acoustic, optical, permeability, dielectric and mechanical behavior of thin films, coatings and bulk polymers; molecular structure, relaxation behavior and energetics of fracture; elastic and viscoelastic behavior of interpenetrating and rubbery networks; effects of ordering in the glassy state and crystallization on physical properties; crystallization under the influence of shear gradients; physical chemistry of polymer composites such as polymer-concrete and filled polymers; interfacial characteristics and interactions in polymer-inorganic systems; mechanical properties of polymer printing plates; NMR studies of polymers in aqueous solutions and gels; ionic motion through polymer films.

## *Major Instrumentation*

Special equipment available for graduate research in chemistry is as follows:

Biochemistry facilities—laboratory fermentor, cold rooms, cell disintegrator, Warburg respirometer, zone and disc electrophoresis apparatus, paper column chromatograph, auto-clave, ultra-low temperature freezers (−90° and −135° C), rotary vaporator, Milli-Q water purification system, shaking heated water baths. Catalytic high pressure reactors—fully automated with on-line gas chromatographs. Cell culture facilities—complete with optical microscopes having fluorescent and photographic capabilities, liquid scintillation equipment. Coal research and analysis facility—complete with ultracentrifuge, gas chromatographs, gel permeation chromatograph, vapor pressure osmometer, dry boxes. Electron microscope—scanning electron microscope-microprobe. Electrophoresis apparatus—automatic. Ellipsometer. Gas adsorption apparatus. Gas chromatographs, including a PE sigma 3 for inverse gas chromatography. Kinetics apparatus—temperature jump method. Liquid chromatographs—high performance for analytical and preparative work. Microcalorimeter—flowing with UV and refractive index detectors. NMR spectrometers—90 MHz multinuclear Fourier transform, 300 MHz solid state, 500 MHz solution state. Photochemistry equipment—lamps and filters for selected wavelength work. Polarographs and chronopotentiometers—recording multipurpose. Radio-tracer equipment, including a gamma counter. Refractometer—differential. Rheometer—Bohlin VOR. Surface analysis analyzer (BET). Spectrometers—uv/visible double beam automated, uv/visible/near ir automated, Fourier transform ir with diffuse reflectance and photoacoustic capability, tunable diode laser ir, Raman microprobe, GC mass spectrometer, fluorometers, phosphorescence, electron spin resonance, Auger, Mossbauer, ESCA, x-ray photoelectron (XPS), low-energy electron diffraction, high resolution electron energy loss, light scattering, electrochemical impedance, photocorrelation for submicron particle analysis. Spectropolarimeter with circular dichroism capability. Tester for power compacts—tensile and compressive. Thermister calorimeter for heats of immersion. Titration equipment—automated and computer interfaced. Vibron elastoviscometers.

## Graduate Courses in Chemistry

**402. Physical Inorganic Chemistry (3)** alternate years
Theories of bonding. Group theoretical principles will be utilized in studies of molecular orbital and ligand field theories of bonding. Prerequisite: Chem 341 or equivalent. Klier

**403. Advanced Topics in Inorganic Chemistry (1-3)** alternate years
Topics of contemporary interest in inorganic chemistry. This course maybe repeated when a different topic is offered. Prerequisite: Chem 307 or equivalent.

**405. Organometallic Chemistry (3)** alternate years
The chemistry of compounds containing carbon to metal bonds. Among topics covered are the following: organic compounds of the representative elements from Group I to IV; the chemistry of ferrocene and related pi-bonded organometallic complexes; metal carbonyl and nitrosyl complexes; dioxygen and dinitrogen complexes;organic synthesis utilizing organometallic catalysts. Kraihanzel

**411. Teaching Internship (3-6)** fall-spring
The preparation, teaching and grading of one or two undergraduate lecture courses with appropriate supervision by senior faculty members. Observation and evaluation of the intern is effected by classroom visits and videotape review. Prerequisite: candidacy in the doctor of arts program or permission of the department chairperson. May be repeated for credit.

**421. Chemistry Research (1-6)**
Research in one of the following fields of chemistry; analytical, inorganic, organic, physical, polymer, biochemistry.

**423. Bio-organic Chemistry (3)** alternate years
An examination of biochemistry on the basis of organic chemical principles. Emphasis on reaction mechanisms of biochemical transformations and methods for elucidation of these mechanisms, ie., kinetics, isotope effects,exchange techniques, inhibition studies, substrate analog effects and organic model studies. Prerequisite: Chem 358. Schray

**424. Medicinal and Pharmaceutical Chemistry (3)** alternate years
Principles of drug design, structure-activity relationships in antibacterial, antimalarial, anti-inflammatory and psychoactive drugs; synthesis and modes of action of pharmacologically active agents radioactive pharmaceuticals. Prerequisite: one year of organic chemistry. Heindel

**432. Advanced Analytical Chemistry (3)** alternate years
Recent developments in analysis of chemical methods. Statistical methods in analytical chemistry: treatment and interpretation of numerical data; design of experiments; application to and discussion of multistage and other methods for separating chemical species. Prerequisite: Chem 332 or equivalent. Ohnesorge

**433. Advanced Topics in Electrochemistry (3)** alternate years
Theory and applications of selected electrochemical techniques;

solutions to mass transport problems, treatment of electron transfer kinetics and kinetics of associated chemical reactions, and critical evaluation of adsorption and other factors associated with electrochemical processes. Prerequisite: Chem 332 or equivalent. Ohnesorge

**435. Advanced Topics in Clinical Chemistry (3)**
Selected areas of clinical chemistry such as chemical toxicology, pathogenic microbial biochemistry in vivo diagnostic methodology, therapeutic drug monitoring, or other advanced topics. May be repeated for credit when a different topic is offered.

**436. Special Topics in Analytical Chemistry (1-3)**
Topics of contemporary interest in analytical chemistry. May be repeated for credit when a different topic is offered. Ohnesorge, Simmons, Daves

**437. Pathophysiological Chemistry (3)** spring
Biochemical basis of human diseases involving abnormal metabolism of proteins, nucleic acids, carbohydrates, and lipids. Emphasis on the correlation of the clinical presentation of disease processes seen as physiological dysfunctions with clinical laboratory methods. Lectures, student presentations, and clinical case discussions. Prerequisite: consent of the department chairperson. Alhadeff

**441. Chemical Kinetics (3)** alternate years
A study of kinetic processes. Phenomenological chemical kinetics; order, mechanism effect of external variables on rate. Theories of the rate constant. Relation between thermodynamics and kinetics. Applications to selected systems such as unimolecular decompositions, molecular beams and diffusion-limited processes. Prerequisite: one year of physical chemistry. Sturm

**443. (Mat 443) Solid-State Chemistry (3)** alternate years
Crystal structure, diffraction in crystals and on surfaces, bonding and energy spectra in solids dielectrics, surface states and surface fields in crystals. Prerequisite: one course in linear algebra and one course in quantum mechanics. Klier

**445. Elements of Physical Chemistry (4)**
Quantum chemistry of simple systems, molecular structure and spectroscopy, statistical and classical thermodynamics. Prerequisite: Chem 341 or its equivalent.

**447. (Biol 447, Phys 447) Experimental Molecular Biology (3)**
The evolution, structure, replication or expression of genes in prokaryotes and eukaryotes. Lectures, discussions, and experiments on the application of genetic analysis and recombinant DNA technology to fundamental aspects of molecular biology.

**451. Physical Organic Chemistry (3)** alternate years
An introduction to quantitative organic chemistry including relationships between structure and reactivity, medium effects on reactions, introduction to orbital symmetry effects in organic reactions, and reaction mechanisms. Prerequisite: Chem 358 or consent of department chairperson. Larsen

**453. Heterocyclic Compounds (3)** alternate years
An intensive study of the syntheses, reactions and properties of heteroaromatic compounds including derivatives of thiophene, pyrrole, furan, indole, pyridine, quinoline, the azoles and the diazines-all considered from the viewpoint of modern theories of structure and reaction mechanisms. Prerequisite: Chem 358. Young

**455. Organic Synthesis (3)** alternate years
Principles of organic synthesis; retrosynthetic analysis, convergent vs. linear sequences, control of relative stereochemistry, chiral substrates and reagents. These and other principles will be illustrated using examples from the recent literature. Prerequisite: Chem 358 or consent of department chairperson. Daves

**458. Topics in Organic Chemistry (3)**
An intensive study of limited areas in organic chemistry. May be repeated when a different topic is offered.

**466. Advanced Organic Preparations (2-3)**
A laboratory course of instruction in advanced techniques of the preparation of organic compounds.

**473. Biochemistry of Complex Carbohydrates (3)** alternate years
Consideration of the structure, function and metabolism of complex carbohydrates (glycolipids, glycoproteins and proteoglycans) with particular emphasis on glycoproteins. The first part of the course will consist of lectures to familiarize the student with basic terms, concepts and processes. The second part will involve critical readings, presentation and discussion of the current primary research literature by class participants. Alhadeff

**475. Advanced Topics in Chemistry (1)**
Audiovisual courses in topics such as acid-base theory, NMR, chromatography, electroanalytical chemistry and mass-spectroscopy interpretation; course material obtained from the American Chemical Society. May be repeated for credit.

**476. Microbial Biochemistry (3)**
Composition, nutrition and metabolism of microorganisms. Major emphasis will be placed on bacteria: the nature of the macromolecules which go into their structures; assembly processes, generation of energy by photosynthetic or chemosynthetic processes, metabolism and control of metabolic reactions. Prerequisite: Chem 372 or equivalent. Merkel

**477. Topics in Biochemistry (1-3)**
Selected areas of biochemistry, such as mechanisms of enzyme action, new developments in the chemistry of lipids, nucleic acids, carbohydrates and proteins. May be repeated for credit when different topics are offered. Prerequisite: consent of the department chairperson.

**479. Biochemical Techniques (3)**
Laboratory studies of the techniques and principles involved in the isolation, identification, and biochemical transformation of carbohydrates, lipids, nucleic acids and proteins. Prerequisite: Chem 371 or its equivalent previously or concurrently. Merkel or Alhadeff

**480. Advanced Biochemical Preparations (1-3)**
An advanced laboratory course in the preparation, isolation, purification, and identification of biochemically produced materials. Emphasis is placed on materials and procedures of current interest in biochemistry. Prerequisite: consent of the department chairperson. Merkel or Alhadeff

**481. Chemistry Seminar (1-6)**
Student presentations on current research topics in the student's discipline but not on subjects close to the thesis. A one-hour presentation and attendance at other presentations are required for credit. May be repeated for credit, up to six times.

**482. (ChE 482, Mat 482) Engineering Behavior of Polymers (3)** spring
Mechanical behavior of polymers. Characterization of experimentally observed viscoelastic response of polymeric solids with the aid of mechanical model analogs. Topics include time-temperature superposition, experimental characterization of large deformation and fracture processes, polymer adhesion, and the effects of fillers, plasticizer, moisture, and aging on mechanical behavior. Robinson

**483. (ChE 483) Emulsion Polymers (3)** fall
Fundamental concepts important in manufacture, characterization, and application of polymer latexes. Topics include colloidal stability, polymerization mechanisms and kinetics, reactor design, characterization of particle surfaces, latex rheology, morphology considerations, polymerization with functional groups, film formation and various application problems. Prerequisite: previous course in polymers. Vanderhoff

**484. (ChE 484, Mat 484) Crystalline Polymers (3)** spring
Morphology and behavior of both polymer single crystals and bulk crystallized system. Relationship between basic crystal physics,

thermal and annealing history, orientation and resulting properties. Thermodynamics and kinetics of transition phenomena and a brief treatment of hydrodynamic properties and their relationship to crystallization and processing properties.

**485. (ChE 485, Mat 485) Polymer Blends and Composites** (3) fall
Synthesis, morphology and mechanical behavior of polymer blends and composites. Mechanical blends block and graft copolymers, interpenetrating polymer networks, polymer impregnated solids and fiber and particulate-reinforce polymers are emphasized. Prerequisite: any introductory course in polymers. Manson, Sperling

**487. Topics in Colloid and Surface Chemistry** (3)
Applications of colloid chemistry; special topics in surface chemistry. Lectures and seminar. May be repeated for credit as different topics are covered. Prerequisite: Chem 395. Fowkes, Micale, Vanderhoff

**488. Advanced Topics in Physical Chemistry (1-3)**
Advanced topics in physical chemistry, such as photochemistry and molecular beam dynamics. Fourier transform spectroscopy, kinetics of rapid reactions, theory of magnetic resonance. May be repeated for credit when different topics are offered.

**489. (ChE 489) Organic Polymer Science II** (3) alternate years
Continuation of Chem 394. Theory and mechanism of ionic vinyl-addition chain-growth polymerization. Chain copolymerization by radical and ionic mechanisms. Mechanism of ring-opening polymerization. Stereochemistry of polymerization including ionic, coordination, and Ziegler-Natta mechanisms. Reactions of polymers, including crosslinking, reaction of functional groups, graft and block copolymers, and polymer carriers and supports. Prerequisite: Chem 394 or equivalent.

**491. Physical Chemistry of Organic Polymer Coatings** (3) alternate years
Pigment/bonder geometry. Oil absorption of pigments. Critical Pigment Volume Concentration concept. Pigment dispersion including surface tension, capillarity, works of dispersion, transfer and flocculation, and dispersing-mixing equipment. Solubility parameter concept. Coating viscosity and viscometers. Evaporation of solvents including water. Coating rheology, mill base letdown, and pigment settling. Film application including leveling, sagging, slumping and draining. Prerequisite: Chem 393 or 394 or equivalent.

**492. (ChE 492) Topics in Polymer Science** (3)
Intensive study of topics selected from areas of current research interest such as morphology and mechanical behavior, thermodynamics and kinetics of crystallization, new analytical techniques, molecular weight distribution, non-Newtonian flow behavior, second-order transition phenomena, novel polymer structures. Credit above three hours is granted only when different material is covered. Prerequisite: Chem 392 or equivalent.

**493. Organic Chemistry of Organic Polymer Coatings** (3) alternate years
Film formation from solution and dispersion, and application of coatings. Mechanism and kinetics of curing glyceride oils, varnishes and alkyd resins, unsaturated polyesters, thermoplastic cellulose, acrylic and vinyl resins, epoxy resins, polyurethanes, amine- and phenol-formaldehyde resins, thermosetting vinyl and acrylic copolymers, water-based systems, natural and synthetic rubber, and silicone resins. New solventless coatings. Prerequisites: Chem 393 and 394 or equivalent.

**494. Quantum Chemistry** (3) alternate years
Principles and applications of quantum mechanics to chemical problems. Applications to chemical bonding, molecular structure, reactivity and spectroscopy. Prerequisite: Chem 445 or consent of the department chairperson. Zeroka

**495. Statistical Thermodynamics** (3) alternate years
Principles and applications of statistical mechanics to chemical problems. A study of the techniques for evaluating the properties of matter in bulk from the properties of molecules and their interactions. Prerequisite: Chem 445 or consent of the department chairperson. Zeroka

# Chinese

See listings under Modern Foreign Languages.

# Civil Engineering

**Professors.** Irwin J. Kugelman, Sc.D. (M.I.T.), *chairman, director, Environmental Studies Center;* J. Hartley Daniels, Ph.D. (Lehigh); George C. Driscoll, Ph.D. (Lehigh); Hsai-Yang Fang, Ph.D. (West Virginia); John W. Fisher, Ph.D. (Lehigh), *director, NSF-ERC Advanced Technology for Large Structural Systems;* Ti Huang, Ph.D. (Michigan); Robert L. Johnson, Ph.D. (Iowa State); Celal N. Kostem, Ph.D. (Arizona); Le-Wu Lu, Ph.D. (Lehigh); Alexis Ostapenko, Sc.D. (M.I.T.); Roger G. Slutter, Ph.D. (Lehigh); Robert M. Sorensen, Ph.D. (Berkeley); David A. VanHorn, Ph.D. (Iowa State); John L. Wilson, Ph.D. (Pittsburgh); Ben-Tseng Yen, Ph.D. (Lehigh).
**Visiting professor.** Johannes H. Egbers, Ing. (HTS. Arnhem).
**Associate professors.** Gerard P. Lennon, Ph.D. (Cornell); Peter Mueller, Dr. sc. techn. (ETH, Zurich); Richard N. Weisman, Ph.D. (Cornell).
**Assistant professors.** Sibel Pamukcu, Ph.D. (L.S.U.); Arup K. Sengupta, Ph.D. (Houston).
**Active emeriti.** Lynn S. Beedle, Ph.D. (Lehigh); George A. Dinsmore, M.S. (Colorado).

Civil engineering occupies a prominent position as one of the major fields in the engineering profession. Civil engineers are concerned with all aspects of the conception, planning, design, construction, operation, and maintenance of major physical works and facilities that are essential to modern life. Civil engineering projects are typically characterized by extreme size, complexity, durability, and cost. Examples include bridges, buildings, transportation facilities, tunnels, coastal facilities, dams, foundations, waterways, sewerage and sewage treatment facilities, and water supply and purification systems.

The undergraduate program includes a strong base of mathematics and the physical sciences, followed by a broad range of courses in the areas of engineering science and civil engineering analysis and design. In civil engineering, the courses extend across the areas of structural, geotechnical, hydraulic, environmental, and transportation engineering, along with planning, economics, probability and statistics, and surveying and measurements. The program is enriched with a series of required and elective courses in the humanities and social sciences. In addition, there are a number of elective opportunities to enable students to pursue areas of particular interest. Over the entire curriculum, emphasis is placed on the development of a solid knowledge of civil engineering fundamentals. Concomitantly, the program is threaded with instruction and opportunities in utilizing the computer, including computer graphics, throughout the field of civil engineering.

The civil engineering program prepares individuals for entry into the engineering profession or for entry into high quality programs of graduate study. With proper selection of electives, students may also prepare for entrance into schools of law or medicine, or into master's-level programs in engineering management or business administration.

For students interested in geological engineering, a five-year program is available, leading to two bachelor of science degrees, in civil engineering and in geological sciences. The program is outlined on page 110.

## Recommended Sequence of Courses

**freshman engineering year** (see page 37)

**sophomore year, first semester** (17 credit hours)

| | |
|---|---|
| Math 23 | Analytic Geometry and Calculus III (4) |
| Geol 161 | Geology for Engineers (3) |
| Mech 1 | Statics (3) |

| | |
|---|---|
| CE 15 | Graphics for Civil Engineering (3) |
| Eco 1 | Economics (4) |

**sophomore year, second semester** (18 credit hours)

| | |
|---|---|
| Math 205 | Linear Methods (3) |
| Mech 11 | Mechanics of Materials (3) |
| CE 112 | Surveying (4) |
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |
| | General Studies Elective (3) |

**junior year, first semester** (17 credit hours)

| | |
|---|---|
| Mech 102 | Dynamics (3) |
| CE 121 | Mechanics of Fluids (3) |
| CE 143 | Soil Mechanics (4) |
| CE 159 | Structural Analysis I (4) |
| | General Studies Elective (3) |

**junior year, second semester** (17 credit hours)

| | |
|---|---|
| CE 117 | Numerical Methods in Civil Engineering (2) |
| CE 160 | Structural Design (4) |
| CE 202 | CE Planning and Engineering Economics (3) |
| CE 222 | Hydraulic Engineering (4) |
| CE 270 | Water Supply and Wastewater Management (3) |

**summer**

| | |
|---|---|
| CE 100 | Summer Employment (0) |

**senior year, first semester** (18 credit hours)

| | |
|---|---|
| Mat 92 | Structure and Properties of Materials (3) |
| CE 207 | Transportation Engineering (3) |
| CE 215 | Probability and Statistics in Civil Engineering (3) |
| | General Studies Elective (3) |
| | Approved Elective (3) |
| | Free Elective (3) |

**senior year, second semester** (18 credit hours)

| | |
|---|---|
| CE 203 | Professional Development (2) |
| CE 290 | CE Design Project (3) |
| | General Studies Elective (3) |
| | Approved Electives (6) |
| | Free Elective (3) |

Elective opportunities total 30 credit hours. The selection of elective courses is to be in consultation with student's academic adviser in the department of civil engineering. A total of 134 credit hours is required for the degree in civil engineering.
* Please refer to description of personal electives, page 36.

## Undergraduate Courses

**15. Graphics for Civil Engineering (3)** fall
Basic theoretical and technical study of computer graphics systems with practical applications in civil engineering. Theory of orthographic and perspective projection. Problems of point, line and plane in descriptive geometry. Emphasis on visualization and geometric logic. Prerequisite: Engr 1.

**100. Summer Employment (0)**
During the summer preceding the senior fall semester, which includes CE 203, students spend at least eight weeks in practical work, preferably in the field that the individual plans to enter after graduation. A letter from the employer confirming the dates of employment is required. Prerequisite: senior standing.

**104. Readings in Civil Engineering (1-3)**
Study of selected technical papers, with abstracts and reports. May be repeated for credit. Prerequisite: consent of the department chairperson.

**112. Surveying (4)** spring
Principles of plane surveying theory and practice applicable to land, engineering, topographic, and control surveys, including the influence of systematic and random errors in field and office measurements, calculations, drawings, and maps. Use of field and office equipment. Field astronomy. Horizontal, vertical, and spiral curves. Prerequisite: Math 21 previously or concurrently or consent of the department chairman. Slutter

**117. Numerical Methods in Civil Engineering (2)** spring
Techniques for computer solution of linear and non-linear simultaneous equations; eigenvalue analysis; finite differences; numerical integration; numerical solutions to ordinary differential equations. Case studies in the various branches of Civil Engineering. Prerequisites: Engineering 1, Math 205. Wilson, Kostem

**121. Mechanics of Fluids (3)** fall
Fluid properties and statics; concepts and basic equations for fluid dynamics. Forces caused by flowing fluids and energy required to transport fluids. Dynamics similitude and modeling of fluid flows. Includes laboratory experiments to demonstrate basic concepts. Prerequisite: Mech 1.

**140. Special Topics in Surveying (3)** spring
Geodetic coordinates, map projections, triangulation, photogrammetry, construction surveys, hydrographic surveys, underground surveys, adjustment of horizontal and vertical control nets, precise leveling, doppler satellite surveys, and aerial pollution control surveys. Field and office work. Prerequisite: CE 41. Limited enrollment. Slutter

**143. Soil Mechanics (4)** fall
Fundamental physical, chemical and mechanical properties affecting the engineering behavior of soils. Identification; classification; permeability; effective stress and pore water pressures; compaction, compression and consolidation; stress-strain behavior and shear strength; laboratory tests for engineering properties; application of theories and principles in engineering practice. Prerequisite: Mech 11 or consent of the department chairperson. Pamukcu

**158. Structural Laboratory (2)** spring
Study of behavior of simple structural members. Planning, testing, and reporting. Acquisition, analysis, and presentation of experimental data. Steel, reinforced concrete, and other materials. Prerequisites: CE 160 and Mat 92, previously or concurrently. Huang

**159. Structural Analysis I (4)** fall
Elastic analysis of statically determinate frames and trusses; deflections by the method of virtual work and moment area; force method analysis of indeterminate structures; moment distribution concept. Prerequisite: Mech 11. Dinsmore, Driscoll

**160. Structural Design (4)** spring
Principles of structural design. Safety and economy. Strength, stability and serviceability criteria. Selection of simple structural members to resist tensile, compressive, bending, and shearing loads. Various structural materials will be covered, especially steel and reinforced concrete. Prerequisite: CE 159. Huang, Lu

**172. Fundamentals of Environmental Pollution (3)** fall
Introduction to water, air, noise, solid waste, radiation and hazardous substance pollution problems. Regulatory standards and rationale, risk and hazardous assessment, economic consequences, technology for control. Prerequisite: Chem 21. Kugelman

**202. CE Planning and Engineering Economics (3)** spring
The planning and management of civil engineering projects. Modeling and optimization methods, project management techniques. Financial decision-making among alternatives. Present value and discounted cash flow analysis; incremental analysis and rate-of-return criteria.

**203. Professional Development (2)** spring
Elements of professionalism; professional ethics; engineering registration; continuing education; responsibilities of an engineer in industry, government, private practice; role of professional and technical societies. Prerequisite: consent of the department chairperson. Johnson

**205. Design Problems (1-6)**
Supervised individual design problems, with report. Prerequisite: consent of the department chairperson.

**207. Transportation Engineering** (3) fall
Principles of the design of transportation facilities with emphasis on highways and airports in the areas of geometric, drainage, and pavement design. Design problems. Prerequisites: CE 112 and senior standing. Slutter

**211. Research Problems (1-6)**
Supervised individual research problems, with report. Prerequisite: consent of the department chairperson.

**215. Probability and Statistics in Civil Engineering** (2) fall
Basic concepts of probability; probability distributions; estimation of parameters; regression and correlation. Analysis of stochastic engineering data. Emphasis on applications to civil engineering problems; structural stability, random loading, risk analysis, traffic flow and water-resource problems, hazard assessment for toxic materials. Prerequisites: Math 23, Mech 11, previously or concurrently. Lu, Mueller

**217. Computer Integrated Civil Engineering Systems** (3) spring
Basic characteristics of modern interactive analysis and design systems. Data structures; 2-D and 3-D graphics modeling; user interfaces; integrated analysis/graphics/data management. Decision tables. Introduction to Knowledge Based Systems and Artificial Intelligence. Numerous case studies and use of interactive systems. In depth experience with computer-integrated systems. Wilson

**222. Hydraulic Engineering** (4) spring
Flow measurements, pipe hydraulics, open-channel flow and river engineering, hydraulic structures and model studies. Laboratory experiments in applied hydraulics. Prerequisite: CE 121.

**244. Foundation Engineering** (3) spring
Application of the theories and principles of soil mechanics to foundation design. Site investigations and engineering tests to evaluate subsoil conditions. Bearing capacity and settlement analyses for building foundations. Lateral loads on retaining walls and bulkheads. Prerequisite: CE 143 or consent of the department chairperson. Fang

**259. Structural Analysis II** (3) spring
Analysis of statically indeterminate structures, methods of slope deflection and moment distribution; consideration of side-sway and nonprismatic members. Influence lines for determinate and indeterminate structures. Flexibility and stiffness matrix methods for computerized analysis. Use of computer library programs. Prerequisite: CE 159. Ostapenko

**261. Structural Steel Design** (3) fall
Design of steel structures, including plate girders, other built-up members, trusses, frames, grillages, shell-type structures and thin-gage members. Additional topics include connections, composite beams, and fatigue and fracture concepts related to structural design. Prerequisite: CE 160. Ostapenko

**263. Structural Concrete Design** (3) fall
Design of reinforced concrete structural members and simple systems, including continuous beams, columns, frames, one- and two-way slabs, and footings. Deflection, cracking, and column slenderness. Introduction to prestressing and torsion. Prerequisite: CE 160. Huang

**270. Water Supply and Wastewater Management (4)**
Quantitative and qualitative evaluation of water sources. Transport, storage, purification and distribution of water supplies. Analysis and design of systems for collection and management of spent and excess storm water; wastewater treatment processes for return to the natural ecosystem. Field trips to water and wastewater process facilities. Laboratory determination of water quality parameters and wastewater characterization for incorporation into management practice. Prerequisites: Chem 21, 22 and CE 121. Johnson

**281. Special Topics (1-6)**
A study of selected topics in civil engineering, not included in other formal courses. Prerequisite: consent of the department chairperson.

**290. CE Design Project** (3) spring
Supervised design projects applying the fundamentals of engineering science and the concepts of planning and systems analysis in the design of practical engineering works. The scope includes needs analysis, formulation of the design problem statement and evaluative criteria; analysis of alternative solutions and the generation of specifications. Economic, social, environmental, aesthetic and safety constraints are considered. Practicing professional engineers are invited to serve as consultants. Written and oral reports are required. Prerequisite: Senior Standing.

**309. Computer Programming** (2) fall
Advanced concepts of Fortran programming in analysis and design. Emphasis on logical program requirements for proper and efficient execution. Addressing and dynamic core allocation. Use of compiler maps and loader maps. Creation and use of permanent files, magnetic tape, and update files. Prerequisite: consent of the department chairperson. Kostem

**322. Hydromechanics** (3)
Ideal fluid flow, vortex flow, creeping motion; laminar boundary layers, turbulent shearing stress and turbulent boundary layers; turbulent jets and diffusion. Prerequisites: Math 205 and CE 222.

**324. (Mech 323) Fluid Mechanics of the Ocean and Atmosphere** (3)
Hydrostatics of the ocean and atmosphere. Vertical stability. Fluid motion in a rotating coordinate system. Geostrophic flow; ocean currents; surface and internal waves. Prerequisite: ME 231 or CE 121.

**325. Engineering Hydrology** (3) fall
Elements of the hydrologic cycle; precipitation, streamflow, evaporation, subsurface water, etc. Flood analysis, hydrographs, flood wave routing. Probability in hydrologic modeling. Hydrology in water resources engineering. Prerequisite: CE 222. Weisman

**326. Ground Water Hydrology** (3) spring
The study of subsurface water, its environment and distribution. Theory of ground water movement, Mechanics of well flow. Sea water intrusion; artificial recharge, basin development. Prerequisite: CE 222.

**328. Open Channel Hydraulics** (3) fall
Energy and momentum concepts, frictional resistance. Rapidly varied flow, gradually varied flow, river controls and channel structures. Prerequisite: CE 222.

**335. Coastal Engineering** (3) fall
Linear wave theory and wave characteristics; survey of non-linear theories; tides, tsunamis, storm surge and basin resonance; wind-generated wave spectra, statistics and forecasting; wave-structure interaction; nearshore circulation and sediment transport; interaction of littoral processes with structures. Prerequisite: CE 121. Sorensen

**336. Harbor and Coastal Engineering Design** (3) spring
Functional and structural design of breakwaters; groins, revetments and other coastal structures; shoreline stabilization; harbor entrance navigation, hydraulics, and stabilization; layout of harbors and marinas; dredging and sediment bypassing; design of marine outfalls and intakes. Prerequisite: CE 335. Sorensen

**341. Ground Improvement Engineering** (3) spring
The mechanisms of soil stabilization; principles and techniques; grouting and injection methods; reinforced earth methods, dynamic consolidation; deep compaction; sand drains; laboratory and field studies; geotextiles and geomembranes. Prerequisite: CE 143 or equivalent. Pamukcu

**342. Experimental Geotechnical Engineering** (3) fall
Experimental studies dealing with the measurement of soil properties in the laboratory and *in situ;* application of these properties to design; consolidation; strength of soils in triaxial compression, tensile strength, and other shear tests, including

measurement of pore water pressures; model design and analysis; dynamic tests; field measurement of *in situ* soil properties; laboratory and field instrumentation. Prerequisites: CE 143 and senior standing. Pamukcu

**343. Seepage and Earth Structures (3)** spring
Long- and short-term stability of embankments and cut slopes; numerical and graphical methods of stability analysis; seepage through soil; design of earth dams, embankments and excavations; influence of embankment stability; construction control, field measurement of pore pressures and earth movements; model studies. Prerequisite: CE 143 or equivalent. Fang

**344. Soil Behavior (3)** spring
Soil mineralogy, bondage, crystal structure and surface characteristics, soil depositional and compositional characteristics, clay-water electrolyte system, ion-exchange reactions, soil fabric, structure and property relationships, volume change, strength and deformation behavior. Prerequisite: CE 143.

**345. Environmental Geotechnology (3)** fall
Behavior of soil and rock and their interaction with various environmental cycles including the atmosphere, biosphere, hydrosphere, lithosphere and geomicrosphere. Soil-water environments, the geomorphic process of soil/rock, mass transport in polluted moist soils, effect of pollutants on soil behavior and foundations, clay liner, slurry wall design. Prerequisite: CE 143.

**352. Structural Dynamics (3)**
Analysis of linear structural systems to time-dependent loads. Free and forced vibration. Classical and numerical methods of solution. Lumped-mass techniques, energy methods, and introduction to matrix formulation of dynamic problems. Application to design. Prerequisites: Math 205, CE 159, and Mech 102. Yen

**359. Plastic Analysis and Design (3)** spring
Plastic analysis and design of steel structures. Strength and behavior of frames and component parts beyond the elastic limit. Methods of predicting strength and deformation in the plastic range. Studies of industrial and multistory frames. Comparison of plastic design techniques with allowable-stress design methods. Current research. Prerequisite: CE 259 or consent of the department chairperson. Driscoll

**360. Structural Design Projects (3)** spring
Design team approach to the analysis and design of bridges in steel and reinforced concrete, including truss, cable-stayed, arch and suspension bridges. Emphasis on the total design concept, including foundations, substructure and superstructure, with consideration of economy, strength, and performance. Prerequisites: CE 261 and CE 263. Daniels

**365. Prestressed Concrete (3)** spring
Principles of prestressing. Analysis and design of basic flexural members. Instantaneous and time-dependent properties of materials. Prestress losses. Additional topics may include continuity, partial prestressing, compression members, circular prestressing, etc. Prerequisite: CE 263 or consent of the department chairperson. Mueller

**370. Water and Wastewater Treatment (3)**
Unit operations and processes in water and wastewater treatment, sedimentation, coagulation, flocculation, filtration, disinfection, chemical treatment, ion exchange, adsorbtion, biological oxidation, sludge dewatering and stabilization. Kinetics, reactor theory, mass balances, application of fundamental physical, chemical and biological principles to analysis and design. Prerequisite: CE 270 or equivalent. Kugelman, Johnson

**374. Environmental Chemistry (3)**
Chemical principles and applications of those principles to the analysis and understanding of aqueous environmental chemistry in natural waters and wastewaters. The chemistry of ionic equilibria, redox reactions, precipitation/dissolution, acid-base concepts, buffer capacity, complexation, hydrolysis and biological reactions. Three to four laboratory experiments. Prerequisite: Chem 31 or equivalent, or CE 270. Sengupta

**375. Environmental Engineering Laboratory (3)**
Application of laboratory based techniques to solution of environmental engineering problems. Chemical and microbiological analysis for key pollution parameters. Use of small pilot and bench scale equipment to generate design parameters. Illustration of techniques for scale-up using parameter values generated in laboratory. Practice in use of automated instrumentation for analysis. Prerequisite: CE 370, previously or concurrently. Sengupta, Kugelman

**378. Water Resources Engineering Design (3)** spring
Project-oriented design utilizing principles of hydraulics, hydrology and environmental engineering. Course will include lectures on selected water resource engineering topics and a design project. Prerequisites: CE 270 and CE 222.

**381. Special Topics (1-3)**
A study of selected topics in civil engineering, not included in other formal courses. Prerequisite: consent of the department chairperson.

**385. Research Procedures Seminar (1)** fall
Planning and execution of research projects, survey of current research, elements of proposals and budgets. Literature search procedures. Presentation of data, and of written and oral reports. Guidelined for visual aids. Driscoll

## Graduate Programs

Graduate studies in civil engineering enable the student to build upon the broad background of undergraduate education in preparation for professional practice at an advanced level, for research and development, or for teaching.

The selection of graduate courses and research opportunities offered in the department permits the development of individual program objectives that may be concentrated in one of the technical specialty areas, or, alternatively, may extend over the broad field of civil engineering. The department offers advanced work in the specialty areas of structural engineering, geotechnical engineering, hydraulic engineering, hydrology, coastal engineering, and environmental engineering, leading to the degrees of master of science, master of engineering, and doctor of philosophy.

A graduate program leading to the M.S. normally is concentrated in one, or possibly two, of the technical specialty areas, and consists of a number of courses designed to fulfill the individual student's program objectives. Each candidate for the M.S. is required to submit a thesis representing three to six credit hours (CE 491, listed below), or alternatively, a report based on a research course of at least three credits (CE 429, 439, 449, 469, 479, or 481). The balance of the program will consist of courses in the specialty area(s).

A graduate program leading to the M.Eng. degree stresses engineering applications and design. The courses may extend across the various specialty areas in civil engineering. Each candidate for the M.Eng. is required to complete an individual engineering project representing three to six credits in place of the thesis or research report required for the M.S.

The doctoral program, which leads to the Ph.D., normally includes courses in the major field, courses in minor fields, and a dissertation presenting results of original research. In addition, each candidate is required to have some education in one or two non-engineering fields. This requirement may be met by taking two courses (200 level or above), or by taking two foreign language courses, or by passing a foreign language proficiency examination. Holders of master's degrees planning to become candidates for the Ph.D. take a qualifying examination at the first opportunity following one semester in residence. After qualification, the program of work is formulated by the candidate, the candidate's departmental Ph.D. committee, and the department chairperson.

The laboratories of the department are located in the Fritz Engineering Laboratory. The laboratory offers outstanding facilities for research and instruction in structural engineering, geotechnical engineering, hydraulic engineering, hydrology, coastal engineering, environmental engineering, and related fields. In particular, the structural testing equipment includes dynamic testing machines, a five-million-pound universal hydraulic testing machine, and other special loading apparatus. Included in the latter are the facilities of

the NSF-ERC ATLSS center located on the mountain top section of the campus. These include the largest 3-dimensional test bed in the U.S.A. and specialized earthquake testing facilities. The recently expanded hydraulic facilities include a wave tank, several flumes, a 10 cfs recirculating flow system, and two multipurpose tanks for model studies. An interdisciplinary relationship with the Environmental Studies Center facilitates the development of research programs in environmental engineering. Brochures describing the research facilities and programs are available on request.

In addition to departmental courses, a number of courses offered by the departments of mechanical engineering and mechanics, chemistry, chemical engineering, materials science and engineering, geological sciences, and biology may also be considered a part of the major field in civil engineering. A list of such courses is available through the department chairperson.

A number of research assistantships and teaching assistantships are available to provide financial aid to students of outstanding promise. The half-time research or teaching activities required of holders of assistantships provide a valuable educational experience that supplements the formal course offerings. The graduate course offerings of the department are programmed to fit the schedule of half-time assistants, and to accommodate part-time students. A very limited number of scholarships and fellowships are available to provide financial aid for full-time study.

## Graduate Courses in Civil Engineering

**403. Analytical Methods in Civil Engineering (3)** fall
Analytical and numerical methods used in various fields of civil engineering. Matrix algebra in engineering analysis. Iterative, differencing, and discretization techniques, energy principles and special methods. Treatment of typical differential equations in civil engineering. Introduction to theory of elasticity with some engineering applications. Prerequisite: Math 205 or equivalent. Ostapenko

**408. Computer Methods in Civil Engineering (3)**
Numerical and computer-oriented methods specially applicable to the solution of complex problems arising in various fields of civil engineering. Solutions of well-and ill-conditioned linear and nonlinear systems. Eigenvalue formulation of stability and dynamic problems. Reduction techniques, integration schemes for large structural systems. Optimal design by linear programming. Introduction to problem-oriented languages and computerized design. Prerequisites: CE 403 or equivalent, and working knowledge of Fortran 77 programming. Kostem or Wilson

**409. Finite Element Method in Structural Mechanics (3)** spring
Basic principles and equations governing the finite element method. Analysis of planar, axisymmetric, plate and articulated structures, with emphasis on analytical modeling. Accuracy and convergence studies, utilizing different discretizations and various types of elements. Case studies include application and extension to material nonlinearities, bridges, containment vessels, and soil-structure interaction. Prerequisites: CE 403 or equivalent; working knowledge of Fortran. Kostem

**424. Surface Water Hydrology (3)**
Advanced analysis and methods in surface water hydrology. Linear and non-linear hydrograph methods. Kinematic wave and other hydraulic routing techniques. Advanced techniques for evaporation, infiltration, snow melt. Prerequisite: CE 325 or equivalent. Weisman

**425. Hydraulics of Sediment Transport (3)**
Hydrodynamic forces on particles, settling velocity. Sediment transport in open channel: tractive force theory, bed load and suspension theory, total load and wash load. Bedform mechanics, cohesive channel hydraulics. Sediment transport in closed conduits. Shore processes and coastline hydraulics. Prerequisite: CE 328 or equivalent. Weisman

**426. Free Surface Flow (3)**
Hydrodynamics of free surface flow phenomena; especially unsteady and spatially varied flow in open channels, and linear and higher order gravity wave theory. Derivation of basic flow equations; presentation of solution techniques and applications to rivers, estuaries and oceans. Prerequisite: consent of instructor. Sorensen and Weisman

**427. Groundwater Transport Modeling (3)**
Groundwater flow, transport and dispersion of contaminants in the groundwater system, including review of selected biological and chemical reactions such as ion exchange, carbonate equilibrium. Computer-based state-of-the-art groundwater contaminant transport models will be used. Selected case studies will be analyzed. Prerequisite: CE 326 or equivalent. Lennon

**428. Advanced Topics in Hydraulics (1-3)**
Recent developments in hydromechanics and hydraulics. Topics to be selected from: wave mechanics, theory of flow through porous media, dispersion, hydrodynamic forces on structures, potential flow, free streamline theory, open channel hydraulics, computer methods. Prerequisites: CE 322 and consent of the department chairperson. May be repeated for credit.

**429. Hydraulic Research (1-6)**
Individual research problems with reports. May be repeated for credit.

**436. Advanced Topics in Coastal Engineering (1-3)**
Advanced study of selected topics in coastal engineering such as: non-linear wave theory, design of coastal structures, shore protection and stabilization, numerical solution of coastal hydrodynamics. Selection of topics will depend on particular qualifications of staff, as well as on the interests of the students. Prerequisite: CE 335. May be repeated for credit.

**439. Coastal Engineering Research (1-6)**
Individual research problems with reports. May be repeated for credit.

**441. Soil Dynamics (3)** fall
Vibration of elementary systems, wave propagation, dynamic soil properties, vibration of soils, foundation vibrations, dynamic bearing capacity, dynamic earth pressure problem and retaining wall, liquefaction of soils, earthquake problems. Prerequisite: CE 244 or consent of the department chairperson.

**443. Advanced Soil Mechanics I (3)** fall
The origin, composition, and physico-chemical properties of soils and their influence on the engineering properties and behavior of soils; transmission of water in saturated and unsaturated soils; advanced theory of compaction; compression and consolidation; theories of shear strength. Prerequisite: a course in soil mechanics. Pamukcu

**444. Advanced Soil Mechanics II (3)** spring
Fundamental and advanced theories of soil mechanics applicable to earth structures and foundation design; stresses in homogeneous and layered systems for ideal elastic, plastic and visco-elastic soils; lateral earth pressures, thermo-geotechnics. Prerequisite: CE 443.

**445. Advanced Foundation Engineering (3)** fall
Current theory and practice relating to the design of foundations for buildings and other structures. Analysis and limitation of settlements; bearing capacity analyses of shallow and deep foundations; flexible and rigid retaining structure design; dynamic effects; anchor and other special foundations; site investigations; design criteria for foundations; load and environmental factors. Prerequisite: a course in soil mechanics. Fang

**447. Advanced Topics in Geotechnical Engineering (3)**
Advanced studies in selected subjects related to geotechnical engineering. The general areas may include: stress-strain-time relationships of soils, colloidal phenomena in soils, ground water flow and seepage, soil dynamics, soil plasticity, numerial methods applied to soil mechanics, earth dam design, theories of layered systems and their application to pavement design, rock mechanics. The studies specifically undertaken in any particular semester depend on the availability of staff and the interest of students. Prerequisite: consent of the department chairperson. May be repeated for credit.

**448. Plasticity and Limit Equilibrium in Geotechnical Engineering (3)** spring
Application of plasticity in soil mechanics, new concepts and theories and the requirements for modeling of actual test performance of soils, limit yield/failure criteria, constitutive relations of stress-strain-time, concepts of critical state soil mechanics, rheological performance, application to problems of stability of slopes, bearing capacity of foundations and active/passive earth pressures. Prerequisite: CE 244, or consent of the department chairperson.

**449. Geotechnical Research (1-6)**
Individual research problems relating to soil engineering, with report. Prerequisite: a course in soil mechanics.

**450. Advanced Structural Theory I (3)** spring
Statical and geometrical stability and degree of statical indeterminacy. Application of energy methods such as virtual work, minimum total potential, minimum complementary energy, and Castigliano's theorems. Introduction to force and displacement matrix analysis of structures. Daniels

**451. Advanced Structural Theory II (3)** fall
Specialized methods of analysis: column analogy moment distribution. General treatment of deformation methods using matrix algebra. Selected topics in structural theory: influence lines, multi-story building frames, space structures. Introduction to finite element method; nonlinear problems. Prerequisite: CE 450. Driscoll

**452. Strength of Structural Members (3)**
Strength of beams, columns, tension components and other structural members under various loading conditions, such as unsymmetrical bending, torsion, beams curved in plane, concept of the shear center. Behavior of member in the elastic and inelastic range. Evaluation of stresses and strains in these members. Prerequisites: CE 159 and Math 205.

**453. Structural Members and Frames (3)** fall
General torsion of thin-walled open, closed, and combined open and closed cross-sections; general instability of thin-walled members; inelastic instability; special problems in stability. Desirable preparation: Mech 415. Prerequisites: CE 403 and consent of the department chairperson. Lu

**454. Plate and Shell Structures (3)**
Plates and slabs loaded transversely in their plane. Buckling and postbuckling behavior of elastic and inelastic plates. Membrane and bending analysis of cylindrical, rotational, and hyperbolic-paraboloidal shells. Emphasis on engineering methods. Design considerations. Prerequisites: CE 403 and consent of the department chairperson. Ostapenko

**455. Advanced Structural Dynamics (3)**
Analysis and design of structures to resist wind, earthquake, and blast loading. Matrix methods and computer applications. Non-linear and elasto-plastic response. Damping characteristics of structures and structural components, spectral analysis, dynamic instability. Characteristics of aerodynamic and seismic forces and nuclear blast. Introduction to vibration of three-dimensional structural systems. Prerequisites: CE 403, CE 352 or Mech 406, and CE 450 or equivalent. Kostem

**456. Behavior and Design of Earthquake Resistant Structures (3)**
Characteristics of earthquakes, effects of earthquakes on structures. Response of linear elastic structures to earthquakes. Response of inelastic structures to earthquakes. Behavior of structural components under cyclic loading. Principles of earthquake-resistant design. Aseismic design procedures and their implementation in codes. Prerequisite: CE 352 or equivalent.

**457. Theory and Design of Steel Structures (3)**
Analysis and design of steel structures; structural connections; composite steel-concrete systems and other components. Consideration of residual stress; brittle fracture; fatigue strength; fastener systems. Study of current research and application to design practice. Fisher

**459. Advanced Topics in Plastic Theory (3)** fall
Fundamentals of the mathematical theory of plasticity; the general theorems of limit analysis and their applications to beams under combined loading, arches, space frames, plates and shells. Limit analysis of two- and three-dimensional problems in soil, concrete, rock, and metal. Current developments. Prerequisite: CE 359.

**460. Civil Engineering Project (1-6)**
An intensive study of one or more areas of civil engineering, with emphasis on engineering design and applications. A written report is required. May be repeated for credit.

**462. Experimental Methods of Structural Analysis (3)**
Analysis of structures using experimental techniques; use of mechanical devices in study of temperature deformations, foundation displacements, and integral action of structures; moire fringe method; theory of similitude with application to model design; structural analogies.

**463. Experimental Methods of Structural Research (3)**
Mechanical properties of structural materials and different procedures of evaluating these properties; experimental methods of stress analysis; statistical analysis of experimental data.

**464. (Mech 416) Analysis of Plates and Shells (3)**
Bending of rectangular and circular plates, plates under lateral loads, plates with thermal and inelastic strains, effect of in-plane forces, large deflections, buckling of plates. Geometry and governing equations of shells, shells of revolution, membrane states, edge solutions, solution by numerical integration, nonsymmetric problems, buckling of shells, applications to pressure vessels. Prerequisites: Math 205; Mech 305 or equivalent course in advanced mechanics of materials. Kalnins or Updike

**465. Advanced Topics in Concrete Structures (3)** fall
Advanced topics in reinforced concrete with or without prestress. Analysis and design for torsion. Limit design concepts. Design of slab systems: strength design method, yield line theory and strip method. Other topics may include composite members, probabilistic basis of design codes, and building and bridge design. Prerequisites: CE 263 and CE 365 or equivalent, or consent of department chairperson. Huang

**466. Concrete Shell Structures (3)**
Analysis and design of concrete shell structures. Folded plates, cylindrical shells, and shells of double curvature. Typical practical problems. Prerequisites: CE 403 and consent of the department chairperson. Ostapenko

**467. Advanced Topics in Structural Engineering (1-3)**
Advanced study of selected topics in structural mechanics and engineering, such as: finite element methods, suspension system; space frames; stability of nonlinear systems; coldformed and lightweight construction; optimization and reliability; second-order phenomena in structures; interaction of structures with the environment; structural use of plastics; composite construction, etc. Selection of topics will depend on particular qualifications of the staff, as well as on the interests of the students. Prerequisite: consent of the department chairperson. May be repeated for credit.

**468. (Mech 415) Stability of Elastic Structures (3)**
Basic concepts of instability of a structure; bifurcation, energy increment, snap-through, dynamic instability. Analytical and numerical methods of finding buckling loads of columns. Postbuckling deformations of cantilever column. Dynamic buckling with nonconservative forces. Effects of initial imperfections. Inelastic buckling. Buckling by torsion and flexure. Variational methods. Buckling of frames. Instability problems of thin plates and shells. Prerequisite: Math 205. Kalnins

**469. Structural Research (1-6)**
Individual research with reports. May be repeated for credit.

**470. Reaction Kinetics in Environmental Engineering (2)**
Theory of reaction kinetics and its application to the design and operation of chemical, physico-chemical and biological reactors in

water and wastewater treatment. Basic design equations for various types of reactors and migration of pollutants in the environment.

**471. Water Treatment Facilities (3)**
Theory and design of water treatment system components. Emphasis on coagulation, flocculation, sedimentation, filtration, and disinfection. Estimation of design parameters from laboratory experiments. Prerequisite: CE 370 or equivalent.

**472. Waste Water Treatment Facilities (3)**
Theory and design of water pollution control systems. Emphasis on film flow and suspended growth biological reactors for organic and nutrient removal. Sludge production, stabilization, dewatering and ultimate disposal. Prerequisite: CE 370 or equivalent.

**473. Advanced Treatment Processes in Environmental Engineering (3)**
Adsorption, ion exchange, reverse osmosis electrodialysis chemical oxidation and stripping in water and wastewater treatment. Kinetics, reactor theories and modeling in water and wastewater treatment systems. Prerequisite: CE 470 or equivalent.

**474. Aquatic Chemistry (3)**
Applying basic principles of aqueous chemistry for quantifying complex, environmental systems. Specific examples of air-water-soil interactions and consequent effects. Heterogeneous equilibria with more than one solid phase. Kinetics and thermodynamics of some important ionic and biological reactions. Prerequisite: CE 374.

**475. Advanced Topics in Environmental Engineering (1-3)**
Advanced concentrated study of a selected topic in environmental engineering such as non-point source pollution control, water reuse systems, new concepts in treatment technology, toxic substances control, etc. Topic is selected by the instructor and student. Courses may include specialized laboratory research, literature review, speciality conference attendance. Prerequisite: Department chairperson approval.

**476. Environmental Engineering Microbiology (3)**
Fundamentals of microbiology and biochemistry applied to environmental systems and water quality control. Systems ecology, energetics and kinetics of microbial growth, nutrition and toxicology, use of microorganisms for pollution monitoring and control. Pathogenicity and disease transmission, water quality using biological indices. Prerequisite: CE 370 or a suitable course in Biology.

**477. Transport of Pollutants in Surface Waters (2)**
Fundamental models of pollution migration in streams, estuaries and oceans. Diffusion, mass transport, dispersion, biological, physical, and chemical interactions. Effects on water quality especially oxygen nutrient and toxics levels. Prerequisites: CE 470, 471, 472.

**478. Toxic and Hazardous Wastes (3)**
Regulations for collection, transportation, disposal and storage of hazardous wastes. Containment systems, monitoring, types of liners, new and available technologies to eliminate or recover the hazardous components of the wastes. Prerequisite: CE 370 or CE 374.

**479. Environmental Engineering Research (1-6)**
Individual research problems in environmental engineering with report. May be repeated for credit.

**481. Special Problems (1-6)**
An intensive study, with report, of a special field of civil engineering which is not covered in the other courses. A design project or an interdisciplinary study of a problem related to civil engineering may also be included. May be repeated for credit.

**483. Graduate Seminar (1-3)**
Study of current topics in civil engineering.

**491. Thesis (1-6)**

**499. Dissertation (1-15)**

# Civil Engineering and Geological Sciences

This program is designed for students interested in geological engineering, and leads to two bachelor of science degrees, in civil engineering and in geological sciences, both awarded at the end of the fifth year.

The program provides alternatives for students who may decide not to complete the two-degree program. Students who make this decision prior to the beginning of the fourth year may qualify at the end of that year for the bachelor of science in civil engineering, as well as a minor in geological sciences. On the other hand, if a student decides after two years to pursue only the bachelor of science in geological sciences, it is possible to complete the requirements in four years. If the decision to work toward this degree is made during the fourth year, at least one additional semester is required to qualify for either bachelor degree. Interested students should consult with the under-graduate officer in the department of civil engineering.

**freshman engineering year** (see page 37)

**second year, first semester** (16 credit hours)

| | |
|---|---|
| Math 23 | Analytic Geometry and Calculus III (4) |
| Mech 1 | Statics (3) |
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) **or** |
| Geol 171 | Introduction to Aqueous Geochemistry (3) |
| Geol 161 | Geology for Engineers (3) |
| CE 15 | Graphics for Civil Engineering (3) |

**second year, second semester** (18 credit hours)

| | |
|---|---|
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |
| Mech 11 | Mechanics of Materials (3) |
| Geol 31 | Historical Geology (3) |
| Mech 102 | Dynamics (3) |
| CE 112 | Surveying (4) |

**third year, first semester** (16 credit hours)

| | |
|---|---|
| Math 205 | Linear Methods (3) |
| CE 121 | Mechanics of Fluids (3) |
| CE 143 | Soil Mechanics (4) |
| Geol 122 | Introduction to Plate Tectonics (3) |
| Geol 133 | Introduction to Mineralogy (3) |

**third year, second semester** (19 credit hours)

| | |
|---|---|
| CE 117 | Numerical Methods in Civil Engineering (2) |
| CE 222 | Hydraulic Engineering (4) |
| CE 270 | Water Supply and Wastewater Management (4) |
| Geol 134 | Introduction to Optical Mineralogy and Crystallography (3) |
| Geol 212 | Paleontology (3) |
| | general studies elective (3) |

**summer**

| | |
|---|---|
| CE 100 | Summer Employment (0)† |

**fourth year, first semester** (19 credit hours)

| | |
|---|---|
| Mat 92 | Structure and Properties of Materials (3) |
| CE 159 | Structural Analysis I (4) |
| Geol 135 | Introduction to Lithology and Petrography (3) |
| Geol 213 | Sedimentology and Stratigraphy (3) |
| Geol 223 | Structural Geology (3) |
| Geol 316 | Hydrogeology (3) |

**fourth year, second semester** (17 credit hours)

| | |
|---|---|
| CE 160 | Structural Design (4) |
| CE 202 | Civil Engineering Planning and Engineering Economics (3) |

| | |
|---|---|
| Geol 112 | Geomorphology (3) |
| Geol 363 | Case Histories in Engineering Geology (3) |
| Eco 1 | Economics (4) |

**summer**

| | |
|---|---|
| Geol 341 | Field Geology (6) |

**fifth year, first semester** (18 credit hours)

| | |
|---|---|
| CE 207 | Transportation Engineering (3) |
| CE 215 | Probability and Statistics in Civil Engineering (3) |
| Geol 301 | Introduction to Geophysics (3) |
| Geol 373 | Geochemical Thermodynamics (3) **or** |
| Chem 187 | Physical Chemistry (3) |
| | general study electives (6) |

**fifth year, second semester** (17 credit hours)

| | |
|---|---|
| CE 203 | Professional Development (2) |
| CE 290 | Civil Engineering Design Project (3) |
| | Civil Engineering elective (3) |
| | approved elective (3)* |
| | general studies electives (6) |

†Eight weeks of summer employment should precede the fourth year. Consult the Civil Engineering Department Chairperson.

*Elective that requires approval of the Civil Engineering Department Chairperson.

A total of 176 credit hours is required to earn both degrees.

# Classics

**Professor.** Charles Robert Phillips, III, Ph.D. (Brown).
**Associate professor.** Amy Richlin, Ph.D. (Yale), *chairperson.*
**Assistant professor.** Julie A. Williams, Ph.D. (Cambridge).

The study of classics examines firstly the origins and growth of Greek and Roman culture in the Mediterranean area and secondly its impact on that area (and others) until the present. This study is by nature interdisciplinary: the study of language and literature, history, philosophy and religion, archaeology, economics and science all contribute to an appreciation of Greco-Roman civilization.

Students in either major or minor programs may concentrate in various combinations of these and other disciplines as they relate to ancient civilization. The diversity of professional interest in the department should encourage the student to follow her or his special interests while simultaneously gaining an overview of classical civilization.

Courses in Ancient Greek and Latin lead to proficiency in language while introducing the student to major literary texts. The Joseph A. Maurer Classics Prize is awarded yearly, at the discretion of the department, to the senior(s) who has demonstrated outstanding achievement in Classics (Ancient Greek or Latin) and/or Classical Civilization. Courses in classical civilization require no knowledge of the ancient languages; they offer introductions to various disciplines of classics with frequent reference to modern perspectives. Upper-level courses tend to be small, fostering closeness between faculty and students.

Petitions are required for freshmen to take 100-level or higher courses and for sophomores to take 200-level or higher courses.

**Major programs.** Students may major either in Classical Civilization or Classics. The Classical Civilization major has no language requirement, although students are encouraged to take language courses in partial fulfillment of major requirements. The Classics major offers a comprehensive view of language and culture; it is possible to begin an ancient language at Lehigh and to complete the major program successfully. Depending on interests and preparation, the student should derive equal educational benefit from either major program. The department welcomes double majors and the educational perspectives to be derived from combining ancient and modern studies.

Classics as a major has stood the test of time, offering helpful preparation for careers in widely diverse fields in the professions, business, and public service. Lehigh classics majors have gone on to law school, the ministry, business school, with appropriate science courses to medical school, graduate work in classics, and to all kinds of entry-level employment.

**Departmental Honors.** A student may be recommended for Departmental Honors by vote of the department based on the student's course work.

**Minor program.** The minor in Classical Civilization or Classics consists of a minimum of fifteen credit hours. Students may focus on any aspect of classical studies, either singly or in combination. The department can arrange individual programs.

**Study abroad.** Lehigh University is a cooperating institution of the Intercollegiate Center for Classical Studies at Rome and of the American School of Classical Studies at Athens. Lehigh students are eligible for tuition grants at Athens and Rome.

Note: Courses designated Clss are taught in English. No knowledge of Latin or Ancient Greek is involved.

## Major in Classical Civilization

This major allows the student to concentrate either in classical archaeology or classical literature while gaining an overview of Greco-Roman culture. No knowledge of ancient languages is required, although students may substitute six credit hours, with the department chairperson's consent, for required major courses. Students are encouraged to individualize their programs by means of appropriate collateral courses chosen in consultation with the department chairperson.

**required preliminary courses** (6 credit hours)

| | |
|---|---|
| Clss 21 | Greek History (3) |
| Clss 22 | Roman History (3) |

**required major courses** (24 credit hours in one of the areas of concentration)

### *Concentration in Archaeology*

| | |
|---|---|
| Clss 82 | Art and Archaeology of Greece (3) |
| Clss 103 | Archaeology of Italy (3) |
| Clss 108 | Ancient Technology (3) |
| Clss 201 | Archaeology: Lands of the Bible (3) |
| Clss 204 | Ancient City and Society (3) |
| Anth 11 | Sociocultural Anthropology (3) **or** |
| Anth 12 | Emergence of Mankind and Culture (3) |

one course chosen from the area of classical literature (3)
one course chosen from the following: Clss 251, Phil 131, RS 111, 114 (3)

### *Concentration in Classical Literature*

| | |
|---|---|
| Clss 5 | Mythology (3) |
| Clss 64 | Homer to Plato: Greek Literature in Translation (3) |
| Clss 152 | Women in Antiquity (3) |
| Clss 161 | Roman Law (3) |

one course chosen from the areas of history or literature (3)
two courses chosen from the area of archaeology (6)
one course chosen from the following: Clss 213, Clss 251, Phil 131, RS 111, 114 (3)
Two courses in either Ancient Greek or Latin may be substituted (see above).

## Major in Classics

This major allows the student to concentrate in Ancient Greek, Latin or both. Specific programs for this major are worked out for each student with due consideration for the individual's particular previous study of the language(s). Students wishing to concentrate in both languages should consult the department chairperson as soon as possible on their arrival at Lehigh. Thus a student may begin

Ancient Greek or Latin at Lehigh and successfully complete a major in it. In general, the program requires as a minimum:

**required preliminary courses** (18 credit hours *maximum,* depending on previous language study)
Clss 21 Greek History (3)
Clss 22 Roman History (3)
either Greek 1, 2, 11, 12 or Latin 1, 2, 11, 12, or appropriate placement as determined by the department chairperson.

**required major courses** (30 credit hours)
twelve credit hours in advanced courses in the major language
six credit hours in the second language, taken at any level
three credit hours in archaeology
three credit hours in philosophy/religion, chosen from the following: Clss 251, Phil 131, RS 111, 114
six credit hours from either classical civilization courses or approved collateral courses.

## Courses in Classical Civilization (Clss)

**Clss 5. Mythology** (3) fall
Introductory study of the myth-making process, both ancient and modern; emphasis on Greek myth.

**Clss 21. (Hist 21) Greek History** (3) fall
The development of civilization from palaeolithic times to the world empire of Alexander the Great. The social, economic, religious, philosophic, artistic and literary development of the ancient world; the origin of political institutions. Phillips

**Clss 22. (Hist 22) Roman History** (3) spring
Rome from its origins to A.D. 476. Political, social and religious developments. Transformation of the late Roman Empire to the early medieval period. Phillips

**Clss 51. Masterworks of Greek and Roman Theatre** (3) fall
Tragedies and comedies from ancient Greece and Rome. Effects of stage conventions and social norms on actor, playwright and play; lectures; discussion.

**Clss 52. Latin Literature in English Translation** (3)
Readings in major genres of Latin literature. Emphasis on epic, Roman comedy, and satire. No knowledge of the Latin language is required.

**Clss 64. Homer to Plato: Greek Literature in Translation** (3)
Lectures and discussions on archaic and classical Greek literature, including the *Iliad;* Hesiod, *Works and Days;* Sappho; the tragic poets; Aristophanes' comedies; and Plato's *Apology* and *Symposium.*

**Clss 82. (Art 82) Art and Archaeology of Greece** (3)
The art and architecture of ancient Greece as revealed by archaeology. Brief surveys of the political and cultural backgrounds to the various artistic periods: Bronze Age, Geometric, Orientalizing, Classical, Hellenistic and Roman. Lectures, slides and films.

**Clss 103. (Arch 103) Archaeology of Italy** (3)
Neolithic, Terramaran, Villanovan and Etruscan cultures. Rome the city: its buildings, monuments and streets, through the kingdom, republic, and empire. Survey of Pompeii, Herculaneum and Ostia. Lectures, readings and reports.

**Clss 108. Ancient Technology** (3) spring
Technology and technique from the stone ages to the beginning of the industrial age; their effects on society. Attitudes to technology in ancient myth literature, philosophy, and religion.

**Clss 131. (Phil 131) Ancient Philosophy** (3) fall
Historical study of philosophy in the classical world from the pre-Socratics to Plato, Aristotle, and the Neo-Platonists, as the originators of the western tradition in philosophy and as interacting with the religious, political, and scientific life of their times. Hare

**Clss 132. Medical Terminology** (1-3)
Basic knowledge of Greek and Latin roots used in medical and health sciences. Rules for combining forms, for recognition of variants. Exercises in etymology.

**Clss 140. (CogS 140) Introduction to Descriptive Linguistics** (3)
Relationship between language and mind; formal properties of language; language and society; how languages change over time.

**Clss 152. Women in Antiquity** (3)
Interdisciplinary study of women in Greece and Rome. Literary, archaeological and historical evidence and approaches. Cross-cultural material. Richlin

**Clss 161. Roman Law** (3)
Examination of Roman legal systems from the *Twelve Tables* to the *Digest* of Justinian. Emphasis on development of legal concepts and their historical context. Readings in primary sources; lectures; discussion. Phillips

**Clss 201. (Art 201) Archaeology: Lands of the Bible** (3)
Chronological survey of archaeological finds from Palaeolithic, Neolithic, Bronze Age, Iron Age, and late cultures in the Near East. Material illustrating the cultures and events of the Bible.

**Clss 204. (Arch 204) Ancient City and Society** (3)
Ancient theories of city and city planning; attitudes to life in the city; rise of urban civilization from Neolithic prototypes through the Near East, Egypt, Greece, Rome, and New World; insights applicable to current urban problems.

**Clss 213. (Rel 213) Ancient Roman Religion** (3)
Religious experience of the Roman people from prehistory to end of the Empire. Nature of polytheism and its interactions with monotheism (Christianity, Judaism). Theories of religion. Emphasis on primary source materials. Phillips

**Clss 215. (Hist 215) Decline and Fall of the Roman Empire** (3)
Political, social, and economic history of the Roman Empire, A.D. 117-A.D. 565. Romanization of the provinces, diffusion of Christianity, and special attention to transformation to medieval period. Includes readings in translation of primary sources. Phillips

**Clss 220. (Hist 220) Golden Age of Greek Democracy** (3)
Greek history of the seventh through fifth centuries B.C. Emphasis on the contrasting political and social systems of Athens and Sparta with consideration of related economic and military history. Attention to art, gender, literature, religion. Discussion and lectures; papers.

**Clss 251. (Rel 251) Classical Mythology** (3)
Myth, religion, and ritual in ancient Greece and Rome. Emphasis on primary sources; introduction to ancient and modern theories of religion. Cross-cultural material.

**Clss 281. Readings** (3) fall
Advanced study of a historical period or theme. Emphasis on primary sources. Prerequisite: Clss 21 or 22 and consent of the department chairperson.

**Clss 282. Readings** (3) spring
Advanced study of a historical period or theme. Emphasis on primary sources. Prerequisite: Clss 21 or 22 and consent of the department chairperson.

## Courses in Ancient Greek

**Grk 1. Elementary Greek** (3) fall
Fundamentals of the Greek language. Readings in the easier authors. Williams

**Grk 2. Elementary Greek** (3) spring
Continued work in Greek vocabulary, forms, and syntax. Selected readings in Greek. Prerequisite: Grk 1. Williams

**Grk 11. Intermediate Greek** (3) fall
Readings in Herodotus, Homer, or Xenophon. Grammar review.

Prerequisite: Grk 1 and 2, or one year of entrance Greek, or consent of department chairperson.

**Grk 12. Intermediate Greek (3)** spring
Plato: *Euthyphro, Apology* and *Crito*, or other dialogues. Prerequisite: Grk 11.

**Grk 111. Greek Drama (3)** fall, alternate years
Representative plays of Sophocles, Euripides and Aristophanes. Literary study of the drama. Prerequisite: Grk 12.

**Grk 112. Greek Drama (3)** spring, alternate years
Continuation of Gk 111. Prerequisite: Grk 12.

**Grk 113. Greek Historians (3)** fall, alternate years
Selections from Herodotus, Thucydides or Xenophon. Study of Greek historiography. Prerequisite: Grk 12.

**Grk 271. Readings (3)** fall
Intensive readings in one author or in a selected genre. Prerequisite: six credit hours at the 100 level and consent of the department chairperson.

**Grk 272. Readings (3)** spring
Intensive readings in one author or in a selected genre. Prerequisite: six credit hours of courses at the 100 level and consent of the department chairperson.

## Courses in Latin

**Lat 1. Elementary Latin (4)** fall
Fundamentals of grammar and syntax. Introduction to Ovid's version of Greek mythology. Emphasis on language structure and vocabulary building.

**Lat 2. Elementary Latin (3)** spring
Easy Latin prose and poetry. Prerequisite: Lat 1 or one to two years of entrance Latin.

**Lat 11. Intermediate Latin (3)** fall
Readings in Latin prose or poetry. Consolidation of reading ability; introduction to literary analysis. Prerequisite: Lat 2 or consent of department chairperson.

**Lat 12. Intermediate Latin (3)** spring
Readings in Latin prose or poetry. Consolidation of reading ability; introduction to literary analysis. Prerequisite: Lat 2 or consent of department chairperson.

**Lat 111. Catullus and Horace (3)** fall
Translation and analysis of selected lyrics, focusing on imagery systems. Introduction to metrics. Prerequisite: Lat 12 or consent of department chairperson.

**Lat 112. Republican Prose: The Roman Revolution (3)** spring
Letters of Cicero; Sallust's *Catiline*. Prerequisite: Lat 12 or consent of chairperson.

**Lat 113. Vergil (3)** fall
Selections from the *Aeneid*. Vergil's creation of a Latin epic and its ambiguities. Metrics. Prerequisite: Lat 12 or consent of chairperson.

**Lat 114. Livy (3)** spring
Selections from the early books of Livy's histories focusing on his creation of a Roman *mythos*. Style. Prerequisite: Lat 12 or consent of chairperson.

**Lat 115. Ovid (3)** fall
Selections from the *Ars Amatoria* and *Metamorphoses* 6-10, focusing on Ovid's problem with ideology. Metrics. Prerequisite: Lat 12 or consent of department chairperson.

**Lat 116. Petronius (3)** spring
Selections from the *Satyricon*, focusing on language usage and epic travesty. Prerequisite: Lat 12 or consent of chairperson.

**Lat 211. Readings (3)** fall
Intensive readings in one author or in a selected genre. Prerequisite: six hours of courses at the 100 level and consent of the department chairperson.

**Lat 212. Readings (3)** spring
Intensive reading in one author or in a selected genre. Prerequisite: six hours of courses at the 100 level and consent of the department chairperson.

**Lat 303. The Roman Epic (3)**
The epic in Latin literature; selections from Lucretius, Catullus and Ovid; critical study of Vergil's *Aeneid*. Prerequisite: six hours of courses at the 100 level and consent of the department chairperson.

# Cognitive Science

Edwin J. Kay, Ph.D. (Lehigh), *professor of computer science, director, Cognitive Science Program.*

Cognitive science is the interdisciplinary study of the relationship between how humans think and how machines think: How can our understanding of the way humans think improve the performance of machines that are meant to behave intelligently? How can our understanding of the ways to make machines behave intelligently improve our understanding of the way humans think? The disciplines most commonly involved in cognitive science studies are anthropology, psychology, computer science, linguistics, and philosophy.

The College of Arts and Sciences offers a major in Cognitive Science, as well as a minor. Because of its broad interdisciplinary character, a cognitive science major prepares a student for a wide variety of careers or graduate study programs. The courses required for the major also readily lend themselves to a double major for those students in the humanities, natural sciences, or computing science who have overlapping interests in cognitive science.

The B.A. with a major in Cognitive Science requires a minimum of 47 credit-hours: 40 within the major itself and at least 7 in collateral areas. All majors are required to take Cognitive Science 101 and 102, a two-semester introduction to cognitive science, preferably in their sophomore year. The remainder of the major is built around a core of four introductory courses, one from each of four disciplines central to cognitive science: cognitive psychology, artificial intelligence, philosophy, and linguistics. In addition, majors must complete six elective courses, two in each of three topical areas related to cognitive science. The final integration of coursework occurs in the required senior seminar, in which students focus on a topic of their choice from a branch of cognitive science.

The collateral course requirements include either Computer Science 11 and 15 or Computer Science 17, and at least the first semester of calculus. Additional coursework in mathematics is strongly recommended, as are: Psychology 1 or 11, Biology 21 and 22, and Anthropology 12.

**Required Introductory Courses**

| | |
|---|---|
| CogS 101 | Introduction to Cognitive Science I (3) fall |
| CogS 102 | Introduction to Cognitive Science II (3) spring |

**Collateral Requirements**

| | |
|---|---|
| CSc 11 | Introduction to Structured Programming (3) **and** |
| CSc 15 | Data Structures (4) **or** |
| CSc 17 | Structured Programming and Data Structures (4) |
| Math 21 | Analytic Geometry and Calculus I (4) **or** |
| Math 31 | Honors Calculus I (4) **or** |
| Math 41 | BMSS Calculus I (3) |

**Disciplinary Core Courses** (12 hours)

| | |
|---|---|
| CSc 230 | Elementary Artificial Intelligence Applications (3) |
| Phil 250 | The Minds of Men and Robots (3) |
| Psyc 117 | Cognitive Psychology (3) |
| CogS 140 | Introduction to Descriptive Linguistics (3) |

**Major Electives** (18 hours)

After completing the introductory sequence and the four core courses, students must complete two courses from any three of the following groups.

Artificial Intelligence and Expert Systems:

| | |
|---|---|
| CSc 262 | Programming Languages (3) |
| CSc 327 | Artificial Intelligence Applications (3) |
| CSc 365 | Natural Language Understanding (3, prereq: CSc 262) |
| CSc 368 | Artificial Intelligence Programming (3, prereq: CSc 262) |

Formal Models:

| | |
|---|---|
| Phil 14 | Foundations of Logic (3) |
| Phil 214 | Logical Theory (3) |
| CSc 261 | Discrete Structures (3, prereq: Math 21 and CSc 11 or Engl 1) |
| CSc 265 | Automata and Formal Grammars (3, prereq: CSc 261) |

Philosophy:

| | |
|---|---|
| Phil 139 | Contemporary Philosophy (3) |
| Phil 220 | Knowledge and Justification (3) |
| Phil 251 | Action, Free Will, and Fate (3) |

Cognitive Psychology:

| | |
|---|---|
| Psyc 307 | Seminar in Cognition (3, prereq: Psyc 117) |
| Psyc 320 | Psycholinguistics (3) |
| Psyc 351 | Cognitive Development in Childhood (3, prereq: Psyc 107 or Psyc 117) |

Sociocultural Influences on Cognition:

| | |
|---|---|
| SPsy 135 | Human Communication (3) |
| SPsy 307 | Attitudes, Attributions, and Actions (3) |
| Anth 376 | Mind, Self and Culture (3) |

Neuroscience:

| | |
|---|---|
| Psyc 176 | Introduction to Cognitive Neuroscience (3) |
| Psyc 177 | Introduction to Physiological Psychology (3) |
| Psyc 373 | Sensation and perception (3, prereq: Psyc 176) |
| Psyc 375 | Neuroanatomy of Behavior (3, prereq: Psyc 177) |

**Senior Seminar** (3 hours)

After completing the sophomore introductory sequence and the four major courses, students pursue their own interests in their selections of major electives. The required senior seminar brings classmates together so that they can teach each other what they have learned in their respective concentrations. This integrates the material in the program and provides students the opportunity to undertake independent projects.

**Recommended Timing of Courses**

| Freshman | Sophomore |
|---|---|
| CSc 11 & 15 or CSc 17 | CogS 101 (fall) |
| Math 21, 31, or 41 | CogS 102 (spring) |
| | 2 Core Courses |
| Junior | Senior |
| 2 Core Courses | Major electives |
| Major electives | CogS 301 (spring) |

### *Minor In Cognitive Science*

The minor in Cognitive Science requires the following courses: CogS 101 and 102 (Introduction to Cognitive Science), CSc 230 (Elementary Artificial Intelligence Applications), Phil 250 (The Minds of Men and Robots), Psyc 117 (Cognitive Psychology), and CogS 140 (Introduction to Descriptive Linguistics).

**Course Descriptions**

**101. Introduction to Cognitive Science I (3)** fall
The conceptual underpinnings of cognitive science, its history and how its constituent disciplines converge on the analysis of intelligent systems.

**102. Introduction to Cognitive Science II (4)** spring
The mathematical tools most widely used in cognitive science.

**140. (Clss 140) Introduction to Descriptive Linguistics (3)**
Relationship between language and mind; formal properties of language; language and society; how languages change over time.

**301. Senior Seminar in Cognitive Science (3)** spring
Integration of the material from cognitive science using topics chosen by the students.

# Computer Engineering

See listings under Computer Science and Electrical Engineering.

# Computer Science and Electrical Engineering

**Professors.** Lawrence J. Varnerin, Ph.D. (M.I.T.), *chairperson;* Donald J. Hillman, Ph.D. (Cambridge, England), *computer science division head;* John J. Karakash, Eng.D. (Hon.) (Lehigh), *distinguished professor emeritus and dean emeritus of the College of Engineering and Applied Sciences;* Robert F. Barnes, Ph.D. (Berkeley); Walter E. Dahlke, Ph.D. (Jena, Germany), *emeritus;* D. Richard Decker, Ph.D. (Lehigh); Richard T. Denton, Ph.D. (Michigan); Nikolai Eberhardt, Ph.D. (Munich, Germany); Bruce D. Fritchman, Ph.D. (Lehigh); Samuel L. Gulden, M.A. (Princeton); Frank H. Hielscher, Ph.D. (Illinois); Carl S. Holzinger, Ph.D. (Lehigh); James C. M. Hwang, Ph.D. (Cornell); Ralph J. Jaccodine, Ph.D. (Notre Dame); Arthur I. Larky, Ph.D. (Stanford); Daniel Leenov, Ph.D. (Chicago), *emeritus;* Edwin J. Kay, Ph.D. (Lehigh); Roger N. Nagel, Ph.D. (Maryland); John J. O'Connor, Ph.D. (Columbia); William E. Schiesser, Ph.D. (Princeton); Eric D. Thompson, Ph.D. (M.I.T.); Kenneth K. Tzeng, Ph.D. (Illinois); Marvin H. White, Ph.D. (Ohio State); Donald R. Young, Ph.D. (M.I.T.).
**Associate professors.** Donald L. Talhelm, M.S. (Lehigh), *electrical engineering division head;* Douglas R. Frey, Ph.D. (Lehigh); Karl H. Norian, Ph.D. (Imperial College, London); Peggy A. Ota, Ph.D. (Pennsylvania); Gerhard Rayna, Ph.D. (Princeton); Meghanad D. Wagh, Ph.D. (I.I.T., Bombay).
**Assistant professors.** Glenn D. Blank, Ph.D. (Wisconsin-Madison); Demetrios Christodoulides, Ph.D. (Johns Hopkins); Miltiadis Hatalis, Ph.D. (Carnegie Mellon); Weiping Li, Ph.D. (Stanford).
**Adjunct lecturers.** Clarence Joh, Ph.D. (SUNY); H. Charles Liebold, M.S. (Lehigh); Gregory J. Smith, M.B.A. (Lehigh).
**Laboratory Co-ordinator:** James A. Butt, M.S. (Lehigh).
**Systems Manager:** Stephen Corbesero, M.S. (Lehigh).

The department of computer science and electrical engineering offers undergraduate and graduate programs of study along with supporting research for students interested in the fields of electrical engineering, computer engineering, and computer science. Lehigh University offers a bachelor of science degree from the College of Engineering and Applied Science in electrical engineering, computer engineering, and computer science, and it offers the bachelor of science and bachelor of arts degree from the College of Arts and Science in computer science. A minor in computer science is available except for students in the College of Engineering and Applied Science.

Graduate study leads to the degrees master of science, master of engineering, and doctor of philosophy in electrical engineering and to the degrees master of science and doctor of philosophy in computer science. Computer engineering graduate students elect either the electrical engineering or the computer science degree designation according to their personal dictates.

While each of the programs has its unique attributes, Lehigh's programs exploit the growing interrelationship among electrical engineering, computer engineering, and computer science. For example, a new computer system which may encompass fundamental algorithmic development, innovative architecture and logic design, and very large scale integrated circuit design and fabrication requires the expertise of individuals knowledgeable across the spectrum. Robotics experts similarly require a broad knowledge spectrum.

The undergraduate programs emphasize the fundamental aspects of their respective areas. Electives permit the student to tailor his program according to his interests and goals, whether they be in preparation for graduate study or entry into industry. Students are free to select courses offered by other departments and are encouraged to do so when appropriate. In this way they can prepare themselves for activities which straddle departmental boundaries or for entry into professional schools such as medicine or management. Students have the opportunity to synthesize and apply their knowledge in a senior design and/or research project.

The graduate programs allow students to deepen their professional knowledge, understanding, and capability within their subspecialties. The thesis is regarded as an essential and important ingredient of these programs. Each graduate student develops a program of study in consultation with his or her graduate advisor.

Key research thrust areas in which departmental research has achieved recognition include:

1. Artificial Intelligence, particularly as applied to manufacturing.
2. Silicon and gallium arsenide semiconductor electronics.

Graduate research is encouraged in these and other areas.

The department maintains a number of laboratories in support of its curricular programs. These laboratories include the electronics circuits laboratory, the microcomputer laboratory, the electromechanics laboratory, and the digital systems laboratory as dedicated undergraduate laboratories. The department has research laboratories in artificial intelligence, computer architectures, cryogenic circuits; design and computing systems; electron device physics; microelectronics fabrication; microprocessor control for energy applications; microwave measurements; microwave monolithic circuits; robotics; and a VLSI measurements laboratory. These laboratories are described more completely in the departmental graduate brochure. These laboratories, among others, are available for undergraduate projects.

Computers and computer usage are an essential part of the student's environment. The University provides mainframe computing on its CDC CYBER 850 and VAX 8530 computers. The CSEE department has state-of-the-art Unix and non-Unix based minicomputers, special and general purpose workstations, and microcomputers in addition to direct access to the machines in the Lehigh University Computer Center (LUCC). The primary departmental computer system consists of two AT&T 3B15 minicomputers running the Unix System V operating system, with dial-in and dial-out capabilities, over 2 Gigabytes of on-line storage, high speed magnetic tape drives, extensive ethernet access. In addition to the central facilities, other department computer resources include Intel, Sun, Tektronix, and Valid workstations and DEC and HP minicomputers used for instruction and research. There are over 60 Intel and PC-Compatible microcomputers available for hardware and software projects at all levels of the curriculum. Peripherals available to all students and faculty include a variety of printers (laser, postscript, and letter quality), plotters (pen and electrostatic), and text and graphics terminals.

Communications among the departmental computer systems is provided by the campus medium-speed serial network, Unix UUCP communication links to several local and distant academic and commercial facilities, a local area network on standard 10 M bit ethernet which is in turn connected to the campus high-speed backbone network. Using these communication lines, the departmental facilities are connected to the National Science Foundation Network (NSF-Net), the Pennsylvania Research and Education Network (PREPNET), Usenet, and BITNET. Students are not now required to have a personal microcomputer but some find such a tool an asset.

A detailed description of the curricular programs follows with a listing of the required courses and with a listing of the departmental course offerings. The departmental courses carry the prefixes CSc for computer science and ECE for electrical engineering. The student is urged to search in both listings for courses appropriate to his career goal.

## Undergraduate Programs

### *Bachelor of Science in Electrical Engineering*

The required courses for this degree contain the fundamentals of linear circuits, systems and control theory, electronic circuits, signal theory, physical electronics, electromagnetic theory, energy conversion, digital systems, and computing techniques. A strong foundation in the physical sciences and in mathematics is required. Approved electives, chosen with the advisor's consent, are selected in preparation for graduate study or entry into industry according to individual interests. The program totals 134 credit hours. The recommended sequence of courses follows:

**freshman year** (see page 37)

**sophomore year, first semester** (17 credit hours)

| | |
|---|---|
| Phys 21, 22 | Introductory Physics II and Laboratory II (5) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| ECE 81 | Principles of Electrical Engineering (4) |
| CSc 33 | Principles of Computer Engineering (4) |

**sophomore year, second semester** (17 credit hours)

| | |
|---|---|
| ECE 108 | Signals and Systems (4) |
| Math 205 | Linear Methods (3) |
| Eco 1 | Economics (4) |
| | general studies (3) |
| | approved elective* (3) |

**junior year, first semester** (17 credit hours)

| | |
|---|---|
| ECE 121 | Electronic Circuits Laboratory (2) |
| ECE 123 | Electronic Circuits (3) |
| ECE 125 | Circuits and Systems (3) |
| Math 231 | Probability and Statistics (3) **or** |
| Math 309 | Theory of Probability (3) |
| | general studies (3) |
| | free elective (3) |

**junior year, second semester** (17 credit hours)

| | |
|---|---|
| ECE 126 | Physical Electronics (3) |
| ECE 136 | Electromechanics (3) |
| ECE 138 | Digital Systems Laboratory (2) |
| ECE 202 | Introduction to Electromagnetics (3) |
| | approved elective* (3) |
| | free elective (3) |

**senior year, first semester** (18 credit hours)

| | |
|---|---|
| ECE 111 | Proseminar (1) |
| ECE 251 | Senior Project I (2) |
| ECE 203 | Introduction to Electromagnetic Waves (3) |
| | general studies (3) |
| | approved electives* (6) |
| | free elective (3) |

**senior year, second semester** (18 credit hours)
approved electives* (12)
general studies (3)
free elective (3)

*Approved electives are subjects predominantly in the area of science and technology. They are not restricted to offerings in the department of computer science and electrical engineering. Students must choose at least one elective in mathematics, at least one elective in either materials, mechanics, thermodynamics, fluid mechanics or physical chemistry, and at least one elective in physics, chemistry or biology. For students interested in solid-state electronics, quantum mechanics is recommended.

## *Bachelor of Science in Computer Engineering*

The required courses for this degree contain the fundamentals of electronic circuits, signal theory, logic design, computer architecture, structured programming, data structures, software engineering, discrete mathematics, and numerical analysis. A strong foundation in the physical sciences and in mathematics is required. Approved electives, chosen with the advisor's consent, are selected in preparation for graduate study or entry into industry according to individual interests. The program totals 135 credit hours. The recommended sequence of courses follows:

**freshman year** (see page 37)

**sophomore year, first semester** (17 credit hours)

| | |
|---|---|
| Phys 21, 22 | Introductory Physics II and Laboratory II (5) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| ECE 81 | Principles of Electrical Engineering (4) |
| CSc 33 | Principles of Computer Engineering (4) |

**sophomore year, second semester** (17 credit hours)

| | |
|---|---|
| CSc 17 | Structured Programming and Data Structures (4) |
| ECE 108 | Signals and Systems (4) |
| CSc 261 | Discrete Structures (3) |
| Math 205 | Linear Methods (3) |
| | general studies (3) |

**junior year, first semester** (17 credit hours)

| | |
|---|---|
| ECE 121 | Electronic Circuits Laboratory (2) |
| ECE 123 | Electronic Circuits (3) |
| CSc 262 | Programming Language (3) |
| Math 231 | Probability and Statistics (3) **or** |
| Math 309 | Theory of Probability (3) |
| | approved elective* (3) |
| | free elective (3) |

**junior year, second semester** (18 credit hours)

| | |
|---|---|
| ECE 116 | Software Engineering (3) |
| ECE 138 | Digital Systems Laboratory (2) |
| ECE 201 | Computer Architecture (3) |
| Eco 1 | Economics (4) |
| | free elective (3) |
| | general studies (3) |

**senior year, first semester** (18 credit hours)

| | |
|---|---|
| ECE 111 | Proseminar (1) |
| ECE 251 | Senior Project I (2) |
| ECE 319 | Digital System Design (3) |
| Math 230 | Numerical Methods (3) **or** |
| Engr 250 | Computer Modeling of Scientific and Engineering Systems (3) |
| | general studies (3) |
| | approved elective* (3) |
| | free elective (3) |

**senior year, second semester** (18 credit hours)
approved electives* (12)
general studies (3)
free elective (3)

*Approved electives are subjects in the area of science and technology. They are not restricted to offerings in the department of computer science and electrical engineering. One elective must be an engineering science elective from another department.

## *Bachelor of Science in Computer Science*

Two degree programs are available to students through either the College of Arts and Science or the College of Engineering and Applied Science. The program offered by the College of Engineering and Applied Science is accredited by the Computer Science Accreditation Board, Inc. The two programs are identical in the fundamental requirements in mathematics and computer science, and the programs are appropriate for entry into management or industrial positions and for continued graduate study. The programs differ in that the students must fulfill the distribution requirements of the respective college. The result of this difference is that the Arts and Science program requires 125 credit hours whereas the College of Engineering and Applied Science program requires 135 credit hours. Students with interests in management, finance, data processing, and information handling may find the Arts and Science College program more appropriate and students with interests in engineering and science applications may find the Engineering and Applied Science College program more appropriate.

The required courses for the degrees contain the fundamentals of discrete mathematics, structured programming, algorithms, computer architectures, compiler design, operating systems, and programming languages. A strong foundation in mathematics is required. The recommended sequence of courses is as follows:

**College of Arts and Science**

**freshman year, first semester** (16 credit hours)

| | |
|---|---|
| Engl 1 | Composition and Literature (3) |
| Math 21 | Analytic Geometry and Calculus I (4) |
| CSc 11 | Introduction to Structured Programming (3) * |
| | distribution (6) |

**freshman year, second semester** (17 credit hours)

| | |
|---|---|
| Engl 2 | Composition and Literature: Fiction, Drama, Poetry (3) |
| Math 22 | Analytic Geometry and Calculus II (4) |
| CSc 15 | Data Structures (4) * |
| | distribution (6) |

**sophomore year, first semester** (17 credit hours)

| | |
|---|---|
| Math 23 | Analytic Geometry and Calculus III (4) |
| CSc 33 | Principles of Computer Engineering (4) |
| CSc 181 | Advanced Programming (3) |
| CSc 261 | Discrete Structures (3) **or** |
| Math 243 | Algebra (3) |
| | distribution (3) |

**sophomore year, second semester** (15 credit hours)

| | |
|---|---|
| Math 205 | Linear Methods (3) |
| ECE 201 | Computer Architecture (3) |
| | approved electives** (6) |
| | distribution (3) |

**junior year, first semester** (15 credit hours)

| | |
|---|---|
| Math 230 | Numerical Methods (3) |
| Math 231 | Probability and Statistics (3) |
| CSc 265 | Automata and Formal Grammars (3) |
| | approved elective** (3) |
| | distribution (3) |

**junior year, second semester** (15 credit hours)

| | |
|---|---|
| CSc 241 | Data Base Systems (3) |
| CSc 262 | Programming Languages (3) |
| CSc 302 | Compiler Design (3) |
| CSc 368 | Artificial Intelligence Programming (3) |
| | distribution (3) |

**senior year, first semester** (15 credit hours)

| | |
|---|---|
| CSc 303 | Operating System Design (3) |

CSc 335 Micro Processor Software Design (3)
approved electives** (6)
distribution (3)

**senior year, second semester** (15 credit hours)
approved electives** (9)
distribution (3)

*With approval, CSc 17, Structured Programming and Data Structures (4), and a 3 credit hour approved elective may be substituted for CSc 11 and CSc 15.
**Approved electives are chosen by the student, with the approval of the major advisor, to support the professional objectives of the student. The approved elective choices must include: a two semester sequence of laboratory science courses acceptable for majors in the field of the courses selected; and, ECE 116, Software Engineering (3) or an approved project course of at least two credit hours. If a two credit hour project course is elected, the program total decreases to 124 credit hours.

**College of Engineering and Applied Science**

**freshman year** (see page 37)

**sophomore year, first semester** (17 credit hours)
Math 23 Analytic Geometry and Calculus III (4)
Phys 21, 22 Introductory Physics II and Laboratory (5)
CSc 17 Structured Programming and Data Structures (4)
Eco 1 Economics (4)

**sophomore year, second semester** (17 credit hours)
Math 205 Linear Methods (3)
CSc 181 Advanced Programming (3)
CSc 33 Principles of Computer Engineering (4)
CSc 261 Discrete Structures (3) **or**
Math 243 Algebra (3)
ECE 81 Principles of Electrical Engineering (4)

**junior year, first semester** (18 credit hours)
Math 231 Probability and Statistics (3) **or**
Math 309 Theory of Probability (3)
CSc 262 Programming Languages (3)
CSc 335 Micro Processor Software Design (3)
CSc 265 Automata and Formal Grammars (3)
general studies (3)
free elective (3)

**junior year, second semester** (18 credit hours)
CSc 241 Data Base Systems (3)
CSc 302 Compiler Design (3)
general studies (3)
approved electives** (3)
CSc 368 Artificial Intelligence Programming (3)
ECE 201 Computer Architecture (3)

**senior year, first semester** (17 credit hours)
Math 230 Numerical Methods (3) **or**
Engr 250 Computer Modeling of Scientific and Engineering Systems (3)
ECE 251 Senior Project I (2)
CSc 303 Operating System Design (3)
general studies (3)
approved elective** (3)
free elective (3)

**senior year, second semester** (18 credit hours)
general studies (3)
approved elective** (12)
free elective (3)

**Approved electives are chosen by the student, with the approval of the major advisor, to support the professional objectives of the student. Either ECE 316 Microprocessor System Design or ECE 319 Digital System Design must be selected as one of the Approved Electives.

## *Bachelor of Arts in Computer Science*

This program of 121 credit hours is for students who desire a strong liberal arts program with a concentration in computer science. The program contains the fundamentals of computer science which include discrete mathematics, structured programming, data structures, programming languages, computer organization, compiler design, and operating systems. The recommended course sequence is as follows:

**freshman year, first semester** (16 credit hours)
Engl 1 Composition and Literature (3)
Math 21 Analytic Geometry and Calculus I (4)
CSc 11 Introduction to Structured Programming (3) *
distribution (6)

**freshman year, second semester** (17 credit hours)
Engl 2 Composition and Literature: Fiction, Drama, Poetry (3)
Math 22 Analytic Geometry and Calculus II (4)
CSc 15 Data Structures (4) *
distribution (6)

**sophomore year, first semester** (16 credit hours)
CSc 261 Discrete Structures (3) **or**
Math 243 Algebra (3)
CSc 33 Principles of Computer Engineering (4)
CSc 181 Advanced Programming (3)
distribution (6)

**sophomore year, second semester** (15 credit hours)
Math 43 BMSS Linear Algebra (3)
ECE 201 Computer Architecture (3)
approved elective (3)
distribution (6)

**junior year, first semester** (15 credit hours)
CSc 262 Programming Languages (3)
CSc 265 Automata and Formal Grammars (3)
distribution (6)
free electives (3)

**junior year, second semester** (15 credit hours)
CSc 302 Compiler Design (3)
distribution (6)
free electives (6)

**senior year, first semester** (15 credit hours)
CSc 303 Operating System Design (3)
distribution (3)
free electives (9)

**senior year, second semester** (12 credit hours)
distribution (3)
free electives (9)

*With approval, CSc 17, Structured Programming and Data Structures (4), and a 3 credit hour approved elective may replace CSc 11 and CSc 15.

## *Minor in Computer Science*

The minor in computer science provides a concentration which includes discrete mathematics, structured programming concepts, programming languages, and computer organization, essential elements of computer science. This minor is not available to students of the College of Engineering and Applied Science. The minor is as follows:

Math 21 Analytic Geometry and Calculus I (4)
CSc 261 Discrete Structures (3)
CSc 11 Introduction to Structured Programming (3) *
CSc 15 Data Structures (4) *
CSc 33 Principles of Computer engineering (4)

CSc 241 Data Base Systems (3) or
CSc 262 Programming Languages (3)

(21 credit hours)

*With approval, CSc 17, Structured Programming and Data Structures (4), can be substituted for CSc 11 and CSc 15 for an 18 credit hour minor.

## Graduate Programs

Graduate programs of study provide a balance between formal classroom instruction and research and are tailored to the individual student's professional goals. The programs appeal to individuals with backgrounds in electrical or computer engineering, computer or information science, mathematics, or the physical sciences. Research is an essential part of the graduate program. Major research areas include:

*Compound Semiconductor Microwave & Quantum Electronics*
Microwave gallium arsenide monolithic integrated circuits, heterojunction device physics and materials. Ultra-high speed phenomena, modelling, packaging subsystem design. Sub-millimeter wave devices, cryogenic noise and magnetotransconductance investigations. Photonic devices, interactions and transmission. Tunnelling microscopy.

*Microelectronics*—Devices, Integrated Circuits, VLSI Design
Silicon integrated circuit technology, processing, fabrication and testing. CMOS, semiconductor device physics, small geometry VLSI, Josephson junction devices. VLSI logic design and verification, computer-aided (CAD), VLSI chip architecture. Non-linear circuit design.

*Artificial Intelligence*—Expert Systems
Expert systems; knowledge-based systems in design, electronics packaging, manufacturing, and construction; intelligent robotics; autonomous vehicles; natural language processing; AI programming languages; learning systems and mechanisms; data models and object-oriented systems; user interfaces; decision-support systems; integration of symbolic and computational processing modes; database interfaces; CAD/CAM/CAE/CIM problems; cognitive science.

*Information and Computer Engineering*
Networking and distributed computing; architecture, protocol specification and verification, loading, routing and allocation, distributed processing, error control, security and protection; real-time processing; pipelining and scheduling, signal processing algorithms, VLSI architectures, speech compression and recognition, concurrent processing; fault tolerant computing; hardware/software redundancy, coding theory, verification and testing.

The Master of Science degree requires the completion of 30 credit hours of work which includes a six credit hour thesis for the E.E. degree and a three credit hour thesis for the C.S. degree. Special topics courses are restricted to six credit hours, and the C.S. degree requires CSc 302, Compiler Design, CSc 411, Advanced Programming Techniques, and CSc 403, Theory of Operating Systems. A program of study must be submitted in compliance with the graduate school regulations. An oral presentation of the thesis is required.

The Master of Engineering degree requires the completion of 30 credit hours of work, which includes design-oriented courses and an engineering project. A program of study must be submitted in compliance with the graduate school rules. An oral presentation of the project is required.

The Ph.D. degree in Electrical Engineering and the Ph.D. degree in Computer Science require the completion of 42 credit hours of work (including the dissertation) beyond the master's degree (48 hours if the master's degree is non-Lehigh), the passing of a departmental qualifying examination appropriate to each degree within one year after entrance into the degree program, the passing of a general examination in the candidate's area of specialization, the admission into candidacy, and the writing and defense of a dissertation. Competence in a foreign language is not required.

Additional graduate program information may be obtained from the department's graduate coordinator.

## Departmental Courses

Courses are listed under the prefixes CSc and ECE. Generally, electrical engineering courses carry the ECE prefix and computer science courses carry the CSc prefix. Computer Engineering courses are likely to be found under either prefix. The reader is urged to consult both listings.

# Computer Science (CSc)

## For Undergraduate Students

**CSc 11. Introduction to Structured Programming (3)**
Algorithmic design and implementation in high-level, block-structured, procedure-oriented languages. No prior computing experience required.

**CSc 15. Data Structures (4)**
Continuation of CSc 11. Data structures using pointer variables. Examination of languages (typified by FORTRAN) not designed with structured programming in mind. Prerequisite: CSc 11.

**CSc 17. Structured Programming and Data Structures (4)**
Algorithmic design and implementation in high level, block-structured, procedure-oriented languages. Recursion, lexical programs, pointers, data structures, and their applications. Previous experience with programming required. NOTE: CSc 17 constitutes an accelerated course for students with some programming experience, which can be used as a prerequisite in place of CSc 11 and 15.

**CSc 33. Principles of Computer Engineering (4)** fall and spring
Microcomputer organization, architecture, and interfacing. Number systems, Boolean algebra, assembly language programming. Includes a software development laboratory. Prerequisite: Engr 1 or CSc 15 or CSc 17 or equivalent.

**CSc 143. Foundations of Information Science (3)**
Fundamental properties of information systems and theories governing information system design. Inherent data structures and representation of knowledge. Logic, data bases, and decision support systems. Real world applications.

**CSc 181. Advanced Programming (3)**
Advanced information structures, list processing, symbolic processing, basic formal language theory, elementary parsing and interpreting algorithms, assembly language, introduction to computer organization. Prerequisite: CSc 15 or 17.

**CSc 190. Special Topics (1-3)**
Supervised reading and research. Prerequisite: consent of the division head.

**CSc 217. (EdT 417) Advanced Instructional Programming in PASCAL (3)**
Continuation of structured programming in PASCAL. Special emphasis on the application of sound,color, and graphics in instructional courseware development. Prerequisite: CSc 11 or EdT 313.

**CSc 221. Low-Cost Personal Retrieval Systems (3)**
Systems for finding information quickly within a personal information collection. Applicable to collections gathered for study, research, hobby, or other purposes. Students develop systems for their own collections. Emphasizes nonmechanical systems, but with some study of possible computer use, including personal computers. For non-computer science people; and also an introduction to retrieval for information science students.

**CSc 230. Elementary Artificial Intelligence Applications (3)**
How computers combine elementary operations to do complex jobs. How computers play chess, compose music, simulate psychiatrists,

produce medical diagnoses. No previous knowledge of computers required.

**CSc 241. Data Base Systems (3)** spring
Data base concepts in terms of formal logic. Knowledge representation and deduction. Data base integrity. Query languages. Prerequisite: CSc 11 or approval of the division head.

**CSc 251. Computers and Language (3)**
Language-related computer applications drawn from a variety of areas such as cryptography, work-processing, linguistics, and artificial intelligence. Prerequisite: CSc 11 or permission of the division head.

**CSc 252. Computers and Society (3)**
A general nontechnical survey of the impact of computers on modern society. Special attention is given to the use of large-scale data banks and retrieval systems, the problems of privacy and file security, and the impact of automation on everyday life.

**CSc 261. (Math 261) Discrete Structures (3)**
Topics in discrete structures chosen for their applicability to computer science and engineering. Sets, propositions, induction, recursion; combinatorics; binary relations and functions; ordering, lattices and Boolean algebra; graphs and trees; groups and homomorphisms. Various applications. Prerequisites: Math 21 and either CSc 11 or Engr 1.

**CSc 262. Programming Languages (3)** fall and spring
Use, structure and implementation of several programming languages. Prerequisite: CSc 15 or 17.

**CSc 265. Automata and Formal Grammars (3)**
Formal languages, automata, parsing. Prerequisite: CSc 261 or Math 261 or Math 243.

**CSc 301. Descriptive Linguistics (3)** fall
Techniques for the description of the phonology, morphology, and syntax of natural languages. Special attention to transformational generative grammar. Rubenstein

**CSc 302. Compiler Design (3)** spring
Principles of artificial language description and design. Sentence parsing techniques, including operator-precedence, bounded-context, and syntax-directed recognizer schemes. The semantic problem as it relates to interpreters and compilers. Dynamic storage allocation, table grammars, code optimization, compiler-writing languages. Prerequisites: CSc 181 and CSc 265.

**CSc 303. Operating System Design (3)** fall
Assemblers, executive systems, multiprogramming, time-sharing. Concurrent tasks, deadlocks, resource sharing. Construction of a small operating system. Prerequisites: CSc 181 or ECE 201.

**CSc 310. (Educ 320, Psyc 320) Psycholinguistics (3)**
Study of the experimental and observational literature on psychological processes involved in the production, comprehension and use of language by adults. Rubenstein

**CSc 311. (EdT 311) Instructional Computing in BASIC (3)**
Introduction to microcomputers and their applications in educational settings. Special emphasis on a structured approach to programming in the BASIC language and on applications of principles of instructional design to the development of microcomputer-based instructional materials. No prior experience with microcomputers or programming is assumed.

**CSc 313. Computer Graphics (3)**
General principles; algorithms; display devices and organization; methods of interaction; design of visual interactive systems. Prerequisite: CSc 181.

**CSc 326. Human Information Processing (3)**
Attention, perception, memory, problem solving, decision making. Focused toward application in artificial intelligence and instructional design.

**CSc 327. Artificial Intelligence Applications (3)**
Computer reasoning, knowledge use (expert systems), and natural language understanding. Emphasis on systems successful in practical use or experimentally. Student development of small-scale systems (programming optional).

**CSc 328. Human Factors (3)**
The cognitive processes relevant to the design and implementation of computer systems; representation of the human role in automation; hardware and software design of interfaces with computer system users; applications of artificial intelligence; human factors issues in robotics.

**CSc 335. Micro Processor Software Design (3)**
Design and development of software for small computers. Interfacing, real-time processing, software-hardware tradeoffs and program efficiency, performance and evaluation. Applications to monitors, operating systems, interpreters, translators and networks. Prerequisites: CSc 33 and 181.

**CSc 338. Data Retrieval Systems (3)**
The design, development, and operation of computer-based systems for the retrieval and manipulation of numerical and non-numerical data contained in machine-readable databases.

**CSc 340. (Math 340) Design and Analysis of Algorithms (3)**
Algorithms for searching, sorting, counting, graph and tree manipultation, matrix multiplication, scheduling, pattern matching, fast Fourier transform. Minimum time and space requirements are established, leading to the notion of abstract complexity measures and the intrinsic complexity of algorithms and problems, in terms of asymptotic behavior. The question of the correctness of algorithms is also treated. Prerequisite: CSc 15 or Math 23 or consent of the division head.

**CSc 343. (EdT 443) Microcomputer-Aided Instruction (3)**
Design and development of microcomputer-assisted instructional units. Students design, program and test microcomputer-aided instructional units as drill, practice, tutorial, and simulation exercises.

**CSc 351. (EdT 351) Cognitive Science (3)**
A synthesis of elements of artificial intelligence, psychology and linguistics; concerned with models of the acquisition, representation, storage, retrieval and application of knowledge.

**CSc 365. Natural Language Understanding (3)**
Design of natural language systems. Survey and implementation of current linguistic and artificial intelligence techniques for morphology, syntax, semantics and discourse. Consideration of interface with nonlinguistic applications, such as databases, robotics. Prerequisite: CSc 262 or consent of instructor. Blank

**CSc 368. Artificial Intelligence Programming (3)** spring
The use of LISP and related languages to simulate intelligence on computers. Prerequisite: CSc 262 or approval of the division head. Rayna

**CSc 374. Information Retrieval Theory (3)**
An introduction to the problems of computerized information storage and retrieval systems. Special attention is given to the logical and mathematical techniques for automatic text-processing, file generation, and inquiry negotiation.

**CSc 390. Special Topics (1-3)** offered as required
An opportunity for advanced work through supervised reading and research. Prerequisite: consent of the division head. May be repeated for credit.

## For Graduate Students

**CSc 403. Theory of Operating Systems (3)**
Principles of operating systems with emphasis on hardware and software requirements and design methodologies for multi-programming systems. Global topics include the related areas of

process management, resource management, and file systems. Prerequisite: CSc 303 or equivalent. Ota

**CSc 409. Theory of Automata and Formal Grammars (3)**
Finite automata. Pushdown automata. Relationship to definition and parsing of formal grammars. Prerequisite: CSc 318.

**CSc 411. Advanced Programming Techniques (3)** spring
Deeper study of structured programming, data structures, backtracking, recursion. Applications of basic concepts of automata theory and formal language theory. Fundamental principles of 'large program' design. Several major programming assignments using Pascal. Prerequisite: CSc 15 or 17 or consent of the division head. Gulden

**CSc 412. Object Oriented Programming**
Objects, messages, classes and inheritance; the model-view-controller paradigm. Prototyping the user interface. Kay

**CSc 413. Robotics and Intelligent Machines (3)**
Software aspects of robot and intelligent machine controls. Fundamental control issues through language and artificial intelligence implementations.

**CSc 414. Expert Systems (3)**
The design and development of knowledge-based expert systems. Rule-based protocols. Knowledge engineering. Programming application. Prerequisite: CSc 368.

**CSc 415. Database Topics (3)**
Design issues in integrated database systems. Database entities and their relationships. Prerequisite: CSc 241 or equivalent.

**CSc 416. Advanced Issues in Knowledge-based Systems (3)**
Advanced techniques and current applications of knowledge-based systems. Emphasis on knowledge engineering techniques through the development of a substantial system. Prerequisite: CSc 414. Hillman and Blank

**CSc 417. Topics in Information Retrieval (3)**
Selected topics in the design of advanced retrieval systems. Prerequisite: CSc 241 or Equivalent.

**CSc 422. Advanced Topics in Compiling (3)**
Topics from general parsers, attributed translation, attribute grammars, two-level grammars, expression optimization, data flow, code optimization, compiler compilers, implementation languages, multi-tasking languages. Prerequisite: CSc 302 or consent of the division head. Gulden

**CSc 437. Program Semantics (3)**
Theories and techniques of program semantics and program verification. Topics may be chosen from denotational semantics, operational semantics, Floyd-Hoare semantics, temporal logic, dynamic logic, algebraic semantics, continuous semantics, recursive function theory or a current semantic theory. Gulden

**CSc 463. Advanced Issues in Natural Language Processing (3)**
Advanced techniques and current applications of natural language systems. Complex syntax and semantics, discourse coherence and planning, natural language interfaces and other applications. Prerequisite: CSc 365 or CSc 465. Blank

**CSc 465. Computational Linguistics (3)**
Design of natural language systems. Application of linguistic theory and artificial intelligence techniques to development of natural language parsers and generators. Analysis of efficiency and extendability of such systems; practical applications. Prerequisite: CSc 262. Blank

**CSc 492. Special Topics (3)**
Topics in computer science not treated in other courses. May be repeated for credit.

# Electrical Engineering (ECE)

## For Undergraduate Students

**ECE 81. Principles of Electrical Engineering (4)** fall and spring
Circuit elements and laws. Behavior of simple linear networks. Characteristics of electronic devices and device models. Introduction to functional circuits, such as operational amplifier and logic devices. Principles of electromechanical energy conversion and power systems. Includes a weekly session for review and discussion. Prerequisite: Math 22. Corequisite: Phys 21.

**ECE 108. Signals and Systems (4)** spring
Continuous and discrete signal and system descriptions using signal space and transform representations. Includes Fourier series, continuous and discrete Fourier transforms, Laplace transforms, and z-transforms. Introduction to sampling. Prerequisite: ECE 81.

**ECE 111. Proseminar (1)** fall
A weekly seminar to acquaint students with current topics in electrical and computer engineering. Students prepare and present oral and written reports that are judged on quality and presentation as well as technical content. Prerequisite: senior standing.

**ECE 116. Software Engineering (3)** spring
Software methodologies, data structures, searching, sorting, recursion, trees and linked lists. Prerequisite: CSc 17 or equivalent.

**ECE 121. Electronic Circuits Laboratory (2)** fall
One lecture and one laboratory per week. Experiments illustrating the principles of operation of electronic devices and their circuit applications. Basic electronic instrumentation and measurement techniques. Corequisite: ECE 123.

**ECE 123. Electronic Circuits (3)** fall
Methods for analyzing and designing circuits containing electronic devices. Topics include device models, basic amplifier configurations, operating point stabilization, frequency response analysis, and computer-aided analysis of active circuits. Prerequisite: ECE 108.

**ECE 125. Circuits and Systems (3)** fall
Formulation of discrete and continuous circuit equations. Complete solutions of difference and differential equations. Network theorems. State space description of discrete and continuous linear systems. Computer-aided circuit analysis. Prerequisites: ECE 108 and Math 205.

**ECE 126. Physical Electronics (3)** spring
Introduction to wave mechanics, statistics and the theory of solid-state materials. Principles of electron emission and conduction and their applications. Treatment of semiconductor devices including: p-n junctions, junction luminescence, p-n lasers, Impatt and Gunn devices, and Hall devices. Prerequisite: ECE 81.

**ECE 136. Electromechanics (3)** spring
Two lecture and one laboratory per week. An experimental introduction to electromechanical energy conversion. Basic concepts of magnetic fields and forces and their application to electrical apparatus including electromechanical transducers, transformers, AC and DC machines. Prerequisite: ECE 81.

**ECE 138. Digital Systems Laboratory (2)** spring
One laboratory and one lecture per week. Digital measurements, digital instrumentation, logic testing. Characteristics of and design techniques for combinational logic and sequential circuits. Prerequisite: CSc 33 or equivalent.

**ECE 162. Electrical Laboratory (1)** spring
Experiments on circuits, machines, and electronic devices. Elementary network theory. Survey laboratory for students not majoring in electrical or computer engineering. Prerequisite: ECE 81.

**ECE 201. Computer Architecture (3)** spring
Digital building blocks, conventional computer structure and

information flow. Mechanization of arithmetic, storage, and control functions. Input-output systems and controllers. Priority interrupt, direct memory access and other overlapping techniques. Architecture of small ('mini') computers; key features of large ('maxi') machines. Digital design simulation. Prerequisite: CSc 33.

**ECE 202. Introduction to Electromagnetics** (3) spring
Elements of vector analysis, Coulomb's law, Biot-Savart's and Ampere's laws, Lorentz Forces, Laplace's and, Maxwell's equations, boundary conditions, methods of solution in static electric and magnetic fields, including finite element numerical approach. Quasistationary fields, inductance. Prerequisite: Math 205, Phys. 21.

**ECE 203. Introduction to Electromagnetic Waves** (3) fall
Uniform plane waves in free space and in materials, skin effect. Waves in transmission lines and waveguides, including optical fibers. Energy and power flow, Poynting's theorem. Reflection and refraction. Resonators. Radiation and diffraction. Prerequisite: ECE 202.

**ECE 212. Control Theory** (3) fall
Introduction to feedback control. Dynamic analysis of linear feedback systems in the time and frequency domain, with emphasis on stability and steady-state accuracy. Major analytical tools: signal-flow graphs, root-locus methods. Nyquist plot, Bode analysis. Cascade compensation techniques. Introduction to sampled data and state-variable concepts. Prerequisite: ECE 125.

**ECE 233. Power System Analysis I** (3) fall
Determination of transmission line constants: transmission line equations. Synchronous generator representation during steady state and transient conditions. Network reduction by matrix partitioning, network solutions by matrix transformations. Symmetrical components and system faults. Sequence impedances of transmission lines, transformer banks and synchronous generators. Prerequisite: ECE 136.

**ECE 234. Power System Analysis II** (3) spring
Application of short-circuit impedance matrix to fault studies. Numerical methods for solution of the load flow problem. Economic dispatch and unit commitment. Basic system stability consideration. Prerequisite: ECE 233.

**ECE 244. Communication Networks** (3)
Introductory theory of two-terminal and four-terminal network synthesis. Transmission lines as network elements. Analog and digital filter theory. Prerequisites: ECE 123 and 125.

**ECE 251. Senior Project I** (2) fall
This capstone course integrates the knowledge and experience acquired in previous and concurrent courses. Emphasis is on design, implementation, test and evaluation of an engineering project in any of the diverse areas of electrical and computing engineering and computer science consistent with the abilities of the student and departmental resources. A written project proposal, periodic progress reports, a final project report, and a project demonstration are required. Prerequisite: Senior standing.

**ECE 252. Senior Project I** (2) spring
Same as ECE 251. May be used to substitute for ECE 251 for those students not following the normal schedule. Also serves as a continuation for those projects beyond the scope of a one semester course. Two-three hour sessions per week. Prerequisite: Senior standing.

**ECE 254. Microwave-Lightwave Laboratory** (2) spring
Basic microwave and optical measurement techniques, design procedures and practical concepts. Practical aspects of fiberoptics, optical transmission, and modulation. Two-three hour sessions per week. Corequisite: ECE 346.

**ECE 256. Honors Project** (1) spring
Open by invitation only to students who have completed ECE 251 Senior Project. Selection is based upon the quality of the senior project with regard to ingenuity, design approach and completeness. The objective of this course is to carry the successful senior projects forward to completion of a technical paper suitable for publication or submission to a technical conference. A written paper and oral presentation are required by mid-semester. Oral presentations will be made before an appropriate public forum. Enrollment limited.

**ECE 303. (Mat 323) Electrical and Physical Characterization of Defects in Semiconductors** (3)
Basic concepts of solid state physics applied to p-n junction theory. Topics include influence of material growth techniques on defect origination; dislocations induced by diffusion; oxidation-induced stacking faults; the role of imperfections on pipe leakage and soft breakdowns. The relation of materials, defects and processing will be highlighted. Jaccodine

**ECE 305. Failure Analysis of Semiconductor Devices** (3)
Review of device fabrication technique. Reliability theory, thermal analysis. Electrostatic damage. Electromigration. Electron microscopy in failure analysis. Effects of mobile ions, built-in charge and interfacial traps on device stability. Term paper. Norian

**ECE 307. Transistor Circuit Applications** (3)
Review of static and dynamic behavior of p-n junctions. Transistor physical electronics, volt-ampere characteristics, and circuit models. Dependence of circuit-model parameters on structure and operating conditions. Tuned amplifiers, feedback amplifiers, and oscillators. Prerequisite: ECE 123.

**ECE 308. Device Electronics for Integrated Circuits** (3)
Physics of metal-semiconductor junction, p-n junctions, and MOS capacitors. Models of Schottky barrier and p-n junction diodes, JFET;s, MOSFET;s, and bipolar transistors. Prerequisite: ECE 126. Norian

**ECE 316. Microcomputer System Design** (3) spring
Content is primarily hardware oriented, but software issues are covered where required. Includes performance characteristics of the more popular devices on the market today. Specific topics include: basic microcomputer structure, bus interconnections, memory systems, serial and parallel interfacing, CRT controllers, interrupt structures, DMA. Prerequisite: CSc 33. Holzinger

**ECE 319. Digital System Design** (3) fall
Digital techniques on the register transfer level. Implementation of microprogramming, intersystem communication, peripheral interfacing and interrupt handling. VLSI design criteria. Application of AHPS for design verification and simulation. Prerequisite: CSc 33. Wagh

**ECE 320. Logic Design** (3) spring
Review of basic switching theory. Implementation using PLA's and other canonic forms. Threshold logic. Synthesis and analysis of sequential circuits. Asynchronous machines. Hazards and races. Design reliability. Prerequisite: CSc 33. Wagh

**ECE 323. Applied Large Scale Integrated Circuits** (3) fall
Operation of various families of logic devices. Study of static and dynamic interconnection problems, including pulse propagation on transmission lines. Static and dynamic RAM's, ROM's, PLA's, SR's, FIFO's and microprocessors. Holzinger

**ECE 332. Design of Linear Electronic Circuits** (3) spring
Introduction to a variety of linear design concepts and topologies, with contemporary audio networks providing many of the concrete examples. Topics include low- and high-level preamps; equalizers and filters; mixers; voltage-controlled amplifiers; input and output stage modifications; power amplifiers; analog switching and digital interface circuitry. Prerequisite: ECE 355. Frey

**ECE 342. Communication Theory** (3) spring
Theory and application of analog and digital modulation. Sampling theory with application to analog-to-digital and digital-to-analog conversion techniques. Time and frequency division multiplexing. Introduction to random processes including filtering and noise problems. Introduction to statistical communication theory with primary emphasis on optimum receiver principles. Prerequisites: ECE 125 and Math 309 or Math 231. Denton

**ECE 343. Digital Signal Processing (3)** fall
Study of one- and two-dimensional orthogonal signal expansions and their discrete representations, including the Discrete Fourier Transform and Walsh-Hadamard Transform. Development of fast algorithms to compute these, with applications to feature extraction and two-dimensional image processing. Introduction to the z-transform representation of numerical sequences with applications to input/output analysis of discrete systems and the design of digital filters. Analysis of the internal behavior of discrete systems using state variables for the study of stability, observability and controllability. Prerequisite: ECE 125. Denton

**ECE 345. Speech Synthesis and Recognition (3)** spring
Application of digital technology to generation and recognition of speech by machines. The analytical tools required for digitizing and encoding speech signals; the methods currently used for synthesizing and recognizing speech; various hardware products available to perform these tasks. Holzinger

**ECE 346. Microwave Circuits and Techniques (3)** spring
Impedance transformation along waveguides. Matching techniques. Applications of Smith Chart. Resonators as circuit elements. Scattering and transfer matrices. S-parameter design of transistor amplifiers. Stability. Noise. Reflection type amplifiers. Prerequisite: ECE 203 or equivalent. Eberhardt

**ECE 350. Special Topics (3)**
Selected topics in the field of electrical and computer engineering not included in other courses. May be repeated for credit.

**ECE 351. Microelectronics (3)** fall
Technology of semiconductor devices and of integrated circuits, including crystal growth and doping, phase diagrams, diffusion, epitaxy, thermal oxidation and oxide masking, photolithography, thin film formation. Effects of these processes on the design of transistors and integrated circuits. Prerequisite: ECE 126 and Phys 31. Thompson or Young

**ECE 355. Applied Integrated Circuits (3)** fall
Emphasis on understanding of terminal characteristics of integrated circuits with excursion into internal structure only as necessary to assure proper utilization in system design. Classes of devices studied include operational amplifiers, digital-to-analog and analog-to-digital converters, linear multipliers, modulators, and phase-locked loops. Prerequisites: ECE 123 and 125. Holzinger

**ECE 361. Introduction to VLSI Circuits (3)** fall
Design of Very Large Scale Integrated Circuits, with emphasis on CMOS Standard Cell design. MOS transistor theory, twin-tub CMOS Technology, physical layout, design rules, parasitic parameter extraction, CMOS gate and switch-level logic design, pass transistors and transmission gates, static and dynamic memories, VLSI system organization. Circuit simulation using SPICE or SLICE. Interactive circuit layout and design rule checking using the VALID SCALDstar systems. This course includes the design and verification of a standard cell. Two one-hour lectures and three hours of design automation laboratory per week. Prerequisite: ECE 123. Hielscher

**ECE 362. Introduction to VLSI System Design (3)** spring
Structured hierarchical approach to the design of digital VLSI circuits and systems. Use of integrated design automation tools for the design, verification, and testability of VLSI circuits. Topics include: systems aspects of VLSI design, hierarchical design methodologies, schematic capture functional verification, timing simulation, design rule checking, parameter extraction. Use of a CMOS standard cell library and of a silicon compiler. This course includes a VLSI design project, with the design to be fabricated by a foundry. Two one-hour lectures and three hours of design automation laboratory per week. Prerequisite: ECE 361. Hielscher

**ECE 387. (ChE 387, ME 387) Digital Control (3)** spring
Sampled-data systems; z-transforms; pulse transfer functions; stability in the z-plane; root locus and frequency response design methods; minimal prototype design; digital control hardware; discrete state variables; state transition matrix; Liapunov stability; state feedback control (2 lectures and one laboratory per week). Prerequisite: ChE 386 or ECE 212 or ME 342 or consent of instructor.

## For Graduate Students

**ECE 404. Computer Networks (3)**
Study of architecture and protocols of computer networks. The ISO model; network topology; data-communication principles, including circuit switching, packet switching and error control techniques; sliding window protocols, protocol analysis and verification; routing and flow control; local area networks; network interconnection; topics in security and privacy. Tzeng

**ECE 407. Linear and Nonlinear Optics (3)**
Gaussian beams. Optical waveguides and resonators. Introduction to laser physics. Crystal optics with attention to nonlinear effects. Harmonic and subharmonic generation. Parametric amplifications. Brillouin and Raman scattering. Classical diffraction theory. Holography with applications. Eberhardt

**ECE 411. Information Theory (3)**
Introduction to information theory. Topics covered include: development of information measures for discrete and continuous spaces study of discrete-stochastic information courses, derivation of noiseless coding theorems, investigation of discrete and continuous memoryless channels, development of noisy channel coding theorems. Fritchman

**ECE 412. Advanced Digital Signal Processing (3)**
Design and analysis of signal processing algorithms, Number theoretic foundations of algorithm design, bilinear algorithms, computational techniques for digital filtering and convolution, Fourier transform and its algorithms, number theoretic transforms and its applications to digital filtering, general and special purpose signal processor designs, application specific techniques in signal processing. Prerequisite: ECE 343 or consent of the department chairman. Wagh

**ECE 413. Data Communication (3)**
Review of data transmission system evolution. Description of devices and techniques used for reliable transmission of data between systems connected by point-to-point data links. Study of protocols and equipments used in terminal-oriented distributed computing systems. Review of different types of communication protocols using queing theory for analysis of their fundamental properties. Denton

**ECE 415. Numerical Processors (3)**
Design strategies for numerical processors, cellular array adders and multipliers, conditional sum and carry-save asynchronous processors, data recoding and Booth's algorithms, use of alternate numerical bases, CORDIC trigonometric calculator, accumulator orientations, bit slice and bit-sequential processors, pipelining and parallel processing considerations. Prerequisite: ECE 201. Wagh

**ECE 431. Topics in Switching Theory (3)**
Emphasis on structural concepts motivated by recent advances in integrated circuit technology. Major topics include: logical completeness, decomposition techniques, synthesis with assumed network forms, systolic architectures, systolic lemma and its applications, bit serial architectures. Prerequisite: ECE 320 or equivalent. Wagh

**ECE 432. Finite State Machines (3)**
Structure of sequential machines. State minimization. State Partitions. Properties and synthesis of finite automata. Linear sequential machines over finite fields. State-space analysis and properties of linear sequential machines. Synthesis of regular expression recognizers. Prerequisite: ECE 320 or consent of the instructor. Wagh

**ECE 433. (ChE 433, ME 433) State Space Control (3)** fall
State-space methods of feedback control system design and design optimization for invariant and time-varying deterministic, continuous systems; pole positioning, observability, controllability, modal control, observer design, the theory of optimal processes and

Pontryagin's Maximum Principle, the linear quadratic optimal regulator problem, Lyapunov functions and stability theorems, linear optimal openloop control; introduction to the calculus of variations; introduction to the control of distributed parameter systems. Intended for engineers with a variety of backgrounds. Examples will be drawn from mechanical, electrical and chemical engineering applications. Prerequisite: ME 343 or ECE 212 or ChE 386 or consent of instructor.

**ECE 434. (ChE 434, ME 434) Multivariable Process Control (3)**
A state-of-the-art review of multivariable methods of interest to process control applications. Design techniques examined include loop interaction analysis, frequency domain methods (Inverse Nyquist Array, Characteristic Loci and Singular Value Decomposition) feedforward control, internal model control and dynamic matrix control. Special attention is placed on the interaction of process design and process control. Most of the above methods are used to compare the relative performance of intensive and extensive variable control structures. Prerequisite: ChE 433 or ME 433 or ECE 433 or consent of instructor.

**ECE 435. Error-Correcting Codes (3)**
Error-correcting codes for digital computer and communication systems. Review of modern algebra concentrating on groups and finite fields. Structure and properties of linear and cyclic codes for random or burst error correction covering Hamming, Golay, Reed-Muller, BCH and Reed-Solomon codes; construction of Goppa codes and their recent generalizations. Decoding algorithms and implementation of decoders. Prerequisite: CSc 261 or equivalent. Tzeng

**ECE 436. (ChE 436, ME 436) Systems Identification (3)**
The determination of model parameters from time-history and frequency response data by graphical, deterministic and stochastic methods. Examples and exercises taken from process industries, communications and aerospace testing. Regression, quasilinearization and invariant-imbedding techniques for nonlinear system parameter identification included. Prerequisite: ChE 433 or ME 433 or ECE 433 or consent of instructor.

**ECE 437. (ChE 437, ME 437) Stochastic Control (3)**
Linear and nonlinear models for stochastic systems. Controllability and observability. Minimum variance state estimation. Linear quadratic Gausian control problem. Computational considerations. Nonlinear control problem in stochastic systems. Prerequisite: ChE 433 or ME 433 or ECE 433 or consent of instructor.

**ECE 444. Microwave Devices (3)**
Basic theory, design theory and intuitive understanding is developed for passive and active devices and special circuitry used today in microwave systems: circulators, isolators, directional coupler, periodic structures, parametric amplifiers, masers, magnetrons, and klystrons. Semiconductor devices are only discussed by their terminal characteristics. Eberhardt

**ECE 447. Nonlinear Phenomena (3)**
Investigation of nonlinear effects in active and passive lumped and distributed circuits with emphasis on methods of analysis as well as physical understanding of jump phenomena, van derPol's theory, stability criteria, phase locking. Transmission line and optical waves in nonlinear media; shock waves, harmonic generation and optical parametric amplification. Eberhardt

**ECE 450. Special Topics (3)**
Selected topics in electrical and computer engineering not covered in other courses. May repeated for credit.

**ECE 451. Physics of Semiconductor Devices (3)**
Crystal structure and space lattices, crystal binding, lattice-waves and vibrations, electrons and atoms in crystal lattices. Quantum mechanics and energy band theory, Carrier statistics, Boltzmann transport theory, interaction of carriers with scattering centers, electronic and thermal conduction. Magnetic effects. Generation and Recombination Theory. Application to p-n junctions. Prerequisites: Phys 31 and ECE 126 or equivalent. Decker or White

**ECE 452. Advanced Semiconductor Diode and Transport Theory (3)**
Properties of metal semiconductor contacts, Schottky barriers, ohmic contacts, hot electrons, intervalley scattering, velocity saturation, secondary ionization, avalanche breakdown. Applications to microwave devices such as avalanche and Gunn diodes, Schottky barrier diodes, tunnel diodes and PIN diodes. Prerequisite: ECE 451. Decker

**ECE 454. Theory of Optoelectronic Devices (3)**
Optical electronics. Theory of radiation, radiative absorption and emission in semiconductors. Applications to optical electronic devices: electroluminescence, light-emitting diodes, lasers. Detection and modulation of optical radiation, solar cells and photodetectors. Prerequisite: ECE 451. Decker

**ECE 455. Theory of Metal Semiconductor and Heterojunction Transistors (3)**
Physics of metal semiconductor and heterojunction field effect transistors (MESFET and HEMT). Theory of semiconductor heterojunctions. Properties of heterojunction bipolar transistors (HBT): Equivalent circuits, applications to microwave amplifiers, oscillators, and switching circuits. Prerequisite: ECE 451. Decker

**ECE 460. Engineering Project (3-6)**
Project work in an area of student and faculty interest. Selection and direction of the project may involve interaction with industry. Prerequisite: consent of department chairperson.

**ECE 461. Theory of Electrical Noise (3)**
Definitions: noise temperature, spectral density. Noise sources: quantum, thermal, shot, generation-recombination, flicker noise. Representation and optimization of noisy networks. Prerequisites: Phys 31 and ECE 126. Decker

**ECE 463. Design of Microwave Solid State Circuits (3)**
Equivalent circuit modeling and characterization of microwave semiconductor devices, principles of impedance matching, noise properties and circuit interaction, introduction to the design of high power and non-linear circuits. Decker

**ECE 468. Solid-State Microelectronics Technology (3)**
Laboratory fabrication of CMOS/Bipolar integrated circuits and device test structures. The emphasis is on practical aspects of IC fabrication including silicon wafer cleaning, gettering of defects, oxidation, diffusion, ion-implantation, photolithography, chemical vapor deposition, plasma and wet-chemical processes, and vacuum evaporation/sputtering of metal and dielectric films.Contamination and safety are emphasized throughout the process sequence. In-process monitors and computer simulation of technology steps are combined with laboratory experiments. Each student fabricates a completed IC 'chip' and performs technology evaluation with on-chip test structures. Registration by consent of instructor. Prerequisite: ECE 351 or equivalent. White and staff

**ECE 474. Analog CMOS VLSI Design (3)**
The fundamentals of analog circuit design with CMOS linear IC techniques. Discrete Analog Signal Processing (DASP) is accomplished with switched-capacitor CMOS circuits. Analog building blocks include operational amplifiers, S/H circuits, comparators and voltage references, oscillators, filters, modulators, phase detectors/shifters, charge transfer devices, etc. Analog subsystem applications are phase-locked loops (PLL's), A/D and D/A converters, modems, sensors, adaptive filters and equalizers, etc. The emphasis in the course is on the physical operation of analog CMOS integration circuits and the design process. Prerequisite: ECE 355 or equivalent. White

**ECE 476. Analysis and Design of Analog Integrated Circuits (3)**
Device and circuit models of bipolar and field effect transistors; bipolar and MOS integrated circuit technology; passive components; parasitic and distributed elements; amplifier gain stages; subthreshold gain stages; current sources and active loads; temperature and supply-independent biasing; output stage design; frequency response and slew rate limitation; operational amplifier and analog multiplier design. Circuit simulation using SPICE or SLICE. Prerequisite: ECE 308 or equivalent. Hielscher

**ECE 478. Analysis and Design of Digital Integrated Circuits (3)**
Large signal models and transient behavior of MOS and bipolar transistors. Basic inverter and logic gate circuits. Noise margins, operating speed, and power consumption of various logic families, including MOS, CMOS, saturated logic TTL, ECL, and I1.2L. Regenerative logic circuits and digital memories. Circuit design and computer aided circuit analysis for LSI and VLSI circuits. Prerequisite: ECE 308. Hielscher

**ECE 479. Advanced MOS VLSI Design (3)**
The design of very large scale NMOS and CMOS integrated circuits. Strong emphasis on device physics, and on novel circuit design approaches for VLSI implementation. Examination of second-order effects involved in designing high-performance MOS digital integrated circuits, with the goal of pushing the design process to the limits determined by our current understanding of semiconductor device physics and of the currently available technologies. The topics include device physics (subthreshold conduction, short-channel effects), important circuit innovations (substrate-bias generators, sense amplifiers), systems aspects (clocking, timing, array structures), as well as static and dynamic circuit implementations. Design project, using VLSI design automation tools. Prerequisites: ECE 308 and ECE 361. Hielscher

**ECE 483. Advanced Semiconductor Devices for VLSI Circuits (3)**
Theory of small geometry devices for VLSI circuits. Emphasis of MOS bipolar device static and dynamic electrical characteristics. Carrier injection, transport, storage, and detection in bulk and interfacial regions. Limitations of physical scaling theory for VLSI submicron device structures. MOS physics and technology, test pattern device structures, charge-coupled devices, MNOS nonvolatile memory devices, and measurement techniques for device and process characterization. The influence of defects on device electrical properties. Prerequisite: ECE 451. White

**ECE 484. Dielectric Materials in VLSI and Optoelectronics (3)**
Electronic and optical properties of silicon dioxide and other dielectric materials, including optical excitations, charge carrier transport and trapping, and interface phenomena. Applications to dielectric crystal, film, used in VLSI technologies. Emphasis on specific topics of current interest. Prerequisite: ECE 451 or equivalent. Young

**ECE 486. Integrated Solid-State Sensors (3)**
The physical operation of sensor-based, custom integrated circuits. Emphasis on the integration of sensors, analog, and digital circuits on a silicon chip with CMOS technology. Sensors include photocells, electrochemical transducers, strain gauges, temperature detectors, vibration and velocity sensors, etc. Analysis of sensor-circuit performance limits including signal-to-noise, frequency response, temperature sensitivity, etc. Examples of sensor-based, custom I.C.'s are discussed and analyzed with CAD modeling and layout. Prerequisite: ECE 451. White

**ECE 493. Solid State Electronics Seminar (3)**
Discussion of current topics in solid-state electronics. Topics selected depend upon the interests of the staff and students and are allied to the research programs of the Sherman Fairchild Laboratory for Solid State Studies. Student participation via presentation of current research papers and experimental work. Prerequisite: consent of instructor. May be repeated for credit.

# Cooperative Undergraduate Education

Certain departments offer limited opportunities to students for cooperative work assignments with industrial or business firms and government agencies. In all cases cooperative work assignments are optional on the part of the student and there is no obligation for the student to accept permanent employment nor for the cooperating organization to offer permanent employment.

When on a cooperative assignment, the student must register for the non-credit course, Cooperative Undergraduate Education, to maintain continuous student status. The fee for this course is established by the University Treasurer. Participation in a cooperative education program does not relieve the student from any regular requirement for the academic curriculum in which he or she is enrolled.

Details of cooperative arrangements vary with different curricula. Each department offering cooperative education will provide the details of its program in writing to interested students.

**200. Cooperative Undergraduate Education (0)**
Supervised cooperative work assignment to obtain practical experience. Prerequisite: Consent of the department chairperson.

# Counseling

See listings under Education.

# Economics

**Professors.** J. Richard Aronson, Ph.D. (Clark), *Clayton Professor;* Nicholas W. Balabkins, Ph.D. (Rutgers); Alvin Cohen, Ph.D. (Florida); Jon T. Innes, Ph.D. (Oregon), *major advisor and curriculum director;* John R. McNamara, Ph.D. (Rensselaer); Eli Schwartz, Ph.D. (Brown), *MacFarlane Professor;* Robert J. Thornton, Ph.D. (Illinois), *chairman.*
**Associate professors.** Thomas J. Hyclak, Ph.D. (Notre Dame); Arthur E. King, Ph.D. (Ohio State); R. Allen Moran, Ph.D. (Massachusetts); Vincent G. Munley, Ph.D. (S.U.N.Y.); Warren A. Pillsbury, Ph.D. (Virginia).
**Assistant professors.** Colleen M. Callahan, Ph.D. (North Carolina); Frank R. Gunter, Ph.D. (Johns Hopkins); Ram Mudambi, Ph.D. (Cornell); Anthony O'Brien, Ph.D. (Berkeley); Larry W. Taylor, Ph.D. (North Carolina).
**Adjunct professors.** Finn B. Jensen, Ph.D. (Southern California); John D. Keefe, M.A. (Miami).

Though economics is variously defined, modern-day definitions generally suggest that it is the study of the principles that govern the efficient allocation of resources. One of the greatest of the 19th century economists who did much to uncover these principles suggested a broader definition. Alfred Marshall described economics as "a study of mankind in the ordinary business of life . . . a part of the study of man." This dual nature of economics, technical and humanistic, is reflected in the fact that at Lehigh the economics major is available to students in the College of Arts and Science as well as in the College of Business and Economics.

As the description below suggests, the economics program is exceptionally flexible once one moves beyond the sophomore year. This flexibility allows the major to be adapted easily to the needs of students with widely varying goals. Although many students choose the economics major in order to secure a firm foundation in economics and finance before entering the business world, many others choose it in preparation for law school or as a complement to their major in government, history, international relations, journalism, mathematics, urban studies, or other disciplines. Naturally, many students who major in economics do so with the intent of pursuing graduate work at the master's or doctor of philosophy levels; others simply want to become "economically literate" in a world where such literacy is increasingly in demand.

At the same time that the program provides flexibility, it also consists of a substantial core of economic theory and related courses. This assures that the student who is uncertain concerning career goals will obtain a broad education in economics and business no matter what upper-level courses are chosen.

Students who are interested in designing a major program in economics suitable to their needs should consult with the major advisor and curriculum director.

## *Major in College of Business and Economics*

Students in the College of Business and Economics electing to major in economics must take the College core courses as listed on pages 35. They must also take at least 15 credit hours of 300 level economics courses beyond the core requirements. These courses may be chosen so as to form an area of specialization or to provide a broad exposure to the various aspects of the discipline. In any case, students should consult with the major advisor in forming their programs.

## *Major in College of Arts and Science*

**Required Courses** (28 credits)

| | |
|---|---|
| Eco 1 | Economics (4) |
| Math 41, 44* | BMSS Calculus I and II (6) |
| Acct 51 | Introduction to Financial Accounting (3) |
| Eco 105 | Intermediate Microeconomic Analysis (3) |
| Eco 119 | Intermediate Macroeconomic Analysis (3) |
| Eco 145 | Statistical Methods (3) |
| Eco 229 | Money and Banking (3) |
| Fin 225 | Business Finance (3) |

*Students who wish to take mathematics beyond calculus should substitute Math 21, 22, and 23 for this requirement.

**Elective Courses** (15 credits)

Students must take 15 credit hours of 300 level economics courses beyond the requirements listed above. Upper-level finance courses may be substituted for economics courses with the approval of the major advisor.

## *Minor in Economics*

A minor in economics consists of 15 credit hours beyond Economics 1. Required courses in the minor are: Economics 105, 119 and 229. Elective courses must be chosen from among the 300-level economics offerings. This minor is available only to students in the College of Arts and Science and in the College of Engineering and Applied Science. Interested students should contact Prof. Vincent Munley.

## Undergraduate Courses In Economics

**1. Economics (4)**
A course in the principles of economics. General topics covered are: the determination of national income; the determination of relative prices; money and banking; monetary and fiscal policy; and government finance. Eco 1 is a prerequisite for all subsequent courses in economics.

**101. (Mgt 101) Introduction to Quantitative Methods (3)**
Mathematical concepts within a business and economics framework: linear algebra, partial derivatives, constrained optimization, and integral calculus. Meets mathematics prerequisite for entering students in the master of business administration program. Not available for credit to undergraduates in the College of Business and Economics.

**105. Intermediate Microeconomic Analysis (3)**
Determination of prices in terms of the equilibrium of the business enterprise and consumer choice in markets of varying degrees of competition; analysis of market structures; determination of wages, rent, interest and profits.

**119. Intermediate Macroeconomic Analysis (3)**
Macroeconomic measurement, theory and policy. The use of alternative macroeconomic models to analyze the level of national income, inflation, unemployment, economic growth; the balance of payments, and exchange rate determination.

**145. Statistical Methods (3)**
Descriptive statistics, probability and probability distributions, sampling, estimation, hypothesis testing, regression and correlation, analysis of variance, nonparametric tests, and index numbers.

## For Advanced Undergraduates And Graduate Students

**229. Money and Banking (3)**
A course dealing with the nature and functions of money, money markets, and commercial and central banking. Effects of the interest rate and money supply on economic activity. Examination and evaluation of current and past monetary policies.

**303. Economic Development (3)**
The principal determinants of economic development theories are examined. Most of the theories are applicable to both the advanced industrial societies and to the poorer nations, but the emphasis is on the developmental process of the countries of the Third World. Cohen

**305. The Economic Development of Latin America (3)**
The course examines the forces at work in the development process in Latin America. Variables considered include the social and political as well as the economic ones. Theories are presented along with their application via the examination of country case studies. Cohen

**309. Comparative Economic Systems (3)**
An analysis of the economic, institutional, and political dimensions of non-market economies in the Soviet Union and China. Balabkins

**310. Economic Evolution (3)**
Structural changes, social transformation, and sources of the long-term growth of the U.S. economy. Balabkins, Thornton

**311. Environmental Economics (3)**
Economic policies for environmental protection. The optimal development of natural resources. The relationship between economic growth and environmental degradation. Case studies in water-quality management. Prerequisite: Eco 105. McNamara

**312. Urban Economics (3)**
The analysis of economic problems related to urban areas; the nature and function of cities; the economic and spatial characteristics of urban activity. Pillsbury

**313. History of Economic Thought (3)**
Study of the evolution of economic science. Critical analysis of the contributions of major economists from the 18th through the 20th centuries. Cohen, Schwartz

**314. Energy Economics (3)**
The economic theory of natural resource allocation over time. Economics of exhaustible and renewable resources. Environmental effects of energy production and consumption. Government regulation of the energy industry. Computer models for energy system forecasting and planning. Prerequisite: Eco 105. McNamara

**315. Industrial Organization (3)**
Structure of American industry. Development of economic models to describe behavior in markets with varying degrees of competition. Technological innovation, relationship between industry concentration and rates of return on capital, role of information and advertising, dynamics of monopoly and oligopoly pricing. Prerequisite: Eco 105. Mudambi

**331. Business History (3)**
The historical context of the development of the modern business firm in the United States. The roles of entrepreneurship, economic structure, technology, and government policy in the shaping of current business practices. Prerequisites: Eco 105 and 119 (Eco 145 is recommended). O'Brien

**332. (Fin 332) Monetary-Fiscal Policy (3)**
Monetary, credit and fiscal policies of governments and central banks

with particular reference to the policies of the United States Treasury and the Federal Reserve System. Prerequisite: Eco 119 or 229. Innes, Schwartz

**333. Managerial Economics (3)**
Models of managerial decision making. Emphasis on the application of economic theory to a variety of business problems. Case studies are employed. Prerequisites: Eco 105 and 145 and Math 41 and 44 (or equivalents) or consent of instructor. Moran

**334. Labor-Management Relations (3)**
An analytical study of the U.S. system of industrial relations, including the evolution of the labor movement, worker choice on the issue of union representation, the process of collective bargaining and the impact of collective bargaining on the management of the firm. Hyclak

**335. Labor Economics (3)**
The economic analysis of labor markets, with emphasis on labor supply and demand, wage and employment theory, and the economics of unionism and other labor market institutions. Thornton

**336. Business and Government (3)**
Analysis of government involvement in the private sector. The problems of monopoly, oligopoly, and externalities in production and consumption. Optimum responses to market failure and analysis of the performance of actual government policies. Prerequisite: Eco 105. Munley, Mudambi

**337. Transportation and Spatial Economics (3)**
The principles of transportation in theory and practice. Transport models and location theories under varying conditions of spatial separation of economic activity. Analysis and evaluation of transportation policies. Prerequisite: Eco 105 or consent of the department chairman. Pillsbury

**339. International Trade (3)**
The theory of international trade; the theory of tariffs; United States commercial policies; the impact of growth and development of the world economy. Gunter

**340. (Fin 340) International Finance (3)**
Analysis of balance of payments and disturbances and adjustment in the international economy; international monetary policies. Prerequisite: Eco. 229. Callahan, Gunter

**343. European Economic Integration (3)**
Analysis of the problems of economic integration with special emphasis on the development of economic cooperation and integration in Western Europe. The methods and the problems of economic planning in the Common Market. United States trade and investments, and European economic integration. Jensen

**346. Business Cycles and Forecasting (3)**
A study of short-term business fluctuations, growth, forecasting and stabilization. Prerequisite: a course in statistics.

**351. Introduction to Mathematical Economics (3)**
Application of mathematical techniques to economic problems of optimization and to economic models. Prerequisites: Math 41 and 44, Eco 105 and 119. Taylor, Innes, Mudambi

**352. Advanced Statistical Methods (3)**
Advanced probability theory, probability and sampling distributions, and classical statistical inference. Index numbers, multiple regression, correlation, and analysis of variance. Spectral analysis, Box-Jenkins auto-regressive and moving average stochastic processes. Prerequisite: a course in statistics. Taylor

**353. (Fin 353) Public Finance: Federal (3)**
A course dealing with government expenditures and revenues, the economics of taxation, and government administration. Aronson, Munley

**354. (Fin 354) Public Finance: State and Local (3)**
The major issues regarding revenues, expenditures, debt and budgeting policy are examined in the light of fiscal principles and economic effects of state and local governments. Special attention is placed on intergovernmental fiscal relations. Aronson, Munley

**357. Econometrics (3)**
Problems in construction, evaluation and use of econometric models. Applications based on research and case studies. Prerequisite: a course in statistics and a course in intermediate economic theory. King

**361. Senior Seminar (3)**
Intensive study and discussion of significant topics in economic policy and theory. Prerequisite: Senior standing as economics major or consent of department chairman.

**362. Martindale Research Seminar (1-3 hrs.)**
This course prepares students to undertake research on various topics in business and/or economics. Admission to this course is limited to student associates of the Martindale Center for the Study of Private Enterprise. Consent of the instructor is required. Course may be repeated for credit up to a maximum total number of 3 hours credit.

**371. Readings in Economics (3)**
Readings in various fields of economics, designed for the student who has a special interest in some field of economics not covered by the regularly scheduled courses. Prerequisite: preparation in economics acceptable to the department chairman.

**372. Readings in Economics (3)**
Continuation of Eco 371.

## For Graduate Students

**401. Basic Statistics for Business and Economics (3)**
Descriptive statistics, probability and probability distributions, estimation, hypothesis testing, correlation and regression, chi-square analysis, and analysis of variance. Computer applications.King, Thornton

**408. Price Theory and Applications (3)**
The role of the price mechanism in the allocation of resources. Theoretical development and empirical estimation of demand, production and cost functions. Analysis of equilibrium price-output determination in competitive and monopolistic markets. Prerequisites: Eco/Mgt 101 (or calculus) and Eco 401 (or equivalent). Munley

**409. Money, Banking, and Macroeconomic Analysis (3)**
The monetary process and the determination of macroeconomic variables: income, output, employment, and prices. Money and capital markets, interest rates, functions of financial intermediaries, monetary and fiscal policy, and recent macroeconomic issues. Prerequisite: Eco 408 (or concurrently). Gunter, Innes, Schwartz

**411. Energy Economics (3)**
The economics of energy production and consumption. Energy system modeling for forecasting and planning. Theoretical models of resource exploitation over time. Regulation of the energy industry. Prerequisites: Eco 408 and Mgt 401 or equivalents. McNamara

**413. Urban Economics (3)**
The application of traditional and spatial economics to the location of economic activity focusing on the urban economic problems of business location, housing, land value, land use and intra-urban transportation. Pillsbury

**415. Applied Econometrics (3)**
Computer applications of standard econometric techniques using regression analysis in a single equation context. Discussion of problems of multicollinearity, heteroscedasticity and autocorrelation. An introduction to simultaneous equation models, identification and estimation problems. Prerequisite: a course in basic statistics. King

**419. Economic History of the United States (3)**
Analysis of the colonial economy, transition to industrialization, and role of trade and transportation in America's development. A

consideration of the importance of slavery to the 19th century American and other New World economies. Origin and development of banking and financial markets. Prerequisites: intermediate microeconomic theory and basic statistics. Callahan

**420. Advanced Macroeconomic Analysis (3)**
Macroeconomic theory and policy. Primary emphasis on theoretical models and policy implications. Prerequisite: Eco 119 or equivalent. Innes, Mudambi

**421. Managerial Economics (3)**
Application of economic analysis to business problems: price and output determination in various markets, analysis of cost and the forecasting of business conditions. Case studies. Prerequisites: Eco/Mgt 101 (or calculus) and Mgt 401 (or equivalent) and course in intermediate microeconomic theory. McNamara, Moran

**432. Advanced Microeconomic Analysis (3)**
A survey of methods of decision-making at the microeconomic level; price theory and econometric applications. Prerequisite: Eco 105 or equivalent.

**433. (Fin 433) Valuation Seminar (3)**
Determinants of financial asset values. The role of uncertainty, imprecise forecasts, risk preferences, inflation, and market conditions. Prerequisite: Fin 411. Beidleman, Buell

**434. Government Regulation of Business (3)**
Analysis of the economic justification for government regulation of private enterprise. Topics include antitrust policy, utilities, and health, safety and environmental regulation. Prerequisite: a course in intermediate microeconomic theory. Munley

**435. Advanced Topics in Microeconomics (3)**
Resource allocation and price determination. Theories of choice of consumers, firms and resource owners under various market forms. Prerequisite: Eco 432 and 145 or equivalents.

**436. Advanced Topics in Macroeconomics (3)**
Models of employment, income, and growth in monetary economies. Policies for economic stability and growth. Prerequisite: Eco 420 or equivalent. Innes

**437. Labor Economics (3)**
The economics of labor markets and various labor market institutions with emphasis on current theoretical and empirical research. Prerequisites: Eco 105 and 145 or equivalents. Thornton

**438. Labor-Management Administration (3)**
A study of the U.S. system of industrial relations, including the evolution and present status of labor law; union organizing efforts; the strategy of negotiations; the substantive provisions of collective bargaining and the administration of collective agreements. Hyclak

**439. History of Economic Thought (3)**
Selected topics in the history of economic thought, with special attention to the origins of modern economic theory. Prerequisite: a graduate course in economic theory. Cohen, Schwartz

**440. Regional Science-Metropolitan Analysis (3)**
A study of the methodology of regional science with emphasis on metropolitan area analysis. A survey of the applications of this methodology to the economic problems of regions and metropolitan areas. Pillsbury

**442. (Fin 442) Foreign Trade Management (3)**
Foreign operations, including export channels in foreign markets, export and import financing, foreign investments, and policies of government and international agencies.

**443. Economics of Environmental Management (3)**
Economic theory of natural resources. Optimal policies for the development of renewable and nonrenewable resources and environmental quality. Prerequisite: Eco 105 or equivalent and Math 44 or equivalent. McNamara

**444. (Fin 444) Banking and Monetary Policy (3)**
Analysis of the U.S. monetary and banking systems. Financial markets. Central bank controls, monetary theory and policy. Prerequisite: a course in money and banking. Innes, Schwartz

**445. International Trade Theory (3)**
Theories of comparative advantage, factor price equalization, trade and welfare, tariffs, trade and factor movements. Prerequisite: Eco 432 or consent of the chairman. Gunter

**446. International Monetary Economics (3)**
Theory of the balance of payments, the microeconomics of international finance, various approaches to balance-of-payments adjustments, theories of foreign exchange rate determination and macroeconomic policy under fixed and flexible exchange rates. Prerequisite: Eco 420 or consent of the chairman. Callahan, Gunter

**447. (Fin 447) Capital and Interest Theory (3)**
Theories of interest and capital. Annuities; applications of present value theory; investment valuation under uncertainty and risk; term structure of interest rates; the theory of savings, cost of capital and capital formation. Prerequisite: a course in finance. Schwartz

**449. (Fin 449) Public Finance (3)**
The economics of public spending and taxation; principles of government debt management; theories of budgeting and cost-benefit analysis and public choice. Aronson, Munley

**451. International Economic Development (3)**
An introduction to the basic theoretical concepts in international economic development and an evaluation of their application by means of a representative sample of the literature. Cohen

**453. Index Numbers and Time Series Analysis (3)**
Classical decomposition of time series, trend analysis, exponential smoothing, spectral analysis and Box-Jenkins autoregressive and moving average methods. Taylor

**454. Forecasting (3)**
Methods of economic and business forecasting. Taylor

**455. Econometric Theory (3)**
Mathematical and statistical specification of economic models. Statistical estimation and tests of parameters in single and multiple equation models. Prediction and tests of structural changes. Prerequisites: background in statistics and calculus. Taylor

**456. Mathematical Economics (3)**
Applications of various mathematical techniques in the formulation and development of economic concepts and theories. Prerequisite: consent of the department chairman. Taylor, Mudambi

**457. (Fin 457) Monetary Theory (3)**
The role of money in the economy from theoretical and empirical perspectives. The influence of money and prices, interest rates, output and employment. Prerequisite: Eco/Fin 444 or equivalent. Innes, Callahan, Gunter

**459. (Fin 459) International Financial Economics (3)**
Analysis of the structure and functioning of the international monetary system, international capital markets, Eurocurrency markets, fixed and floating exchange rates, and the role of international monetary institutions in foreign exchange risk management. Callahan, Gunter

**461. Methodology in Theory and Research (3)**
Foundations of theory construction and empirical research in economics.

**463. Advanced Statistics for Business and Economics (3)**
An expanded development of statistical concepts necessary for business and economic research. Topics include probability theory, sets, density functions and distributions, sampling distributions, point estimation, moment generating functions, maximum likelihood, classical statistical inference, power functions, likelihood ratio tests and non-parametric tests. Prerequisites: Math 41 and Math 44 or equivalents. Taylor

**465. Topics in Industrial Organization (3)**
Theoretical and empirical analysis of how the structure, organization, and behavior of firms and industries affect economic performance and economic welfare. Prerequisite: Eco 408 or equivalent. Mudambi

**471. Special Topics in Economics (3)**
Extended study of an approved topic not covered in scheduled courses.

**472. Special Topics in Economics (3)**
Continuation of Eco 471.

**490. Thesis**

**499. Dissertation in Economics and Business**

# College of Education

Alden J. Moe, *dean*.

The College of Education is organized into two departments and eight program areas. The departments are the Department of Counseling Psychology, School Psychology, and Special Education and the Department of Leadership, Instruction, and Technology.

The department faculties and program offerings are listed below followed by descriptions of course offerings. More details on specific degree requirements and on University Graduate School regulations can be found in the section on Advanced Study and Research.

## Department of Counseling Psychology, School Psychology, and Special Education

**Professors.** Raymond Bell, Ed.D. (Lehigh), *Chairperson;* J. Gary Lutz, Ed.D. (Lehigh); John A. Mierzwa, Ed.D. (Harvard).

**Associate professors.** Diane M. Browder, Ph.D. (Virginia); Edward S. Shapiro, Ph.D. (Pittsburgh); William B. Stafford, Ed.D. (Indiana).

**Assistant professors.** Christine L. Cole, Ph.D. (Wisconsin-Madison); Brenda K. Hawks, Ph.D. (Virginia Commonwealth); Donna M. Murphy, Ph.D. (Virginia); Timothy L. Turco, Ph.D. (Louisiana State).

**Adjunct professors.** Ellen N. Cohen, Ph.D. (Columbia); Frank M. Dattilio, Ph.D. (Temple); Timothy E. Ring, Ed.D. (Arkansas); Mervin P. Smolinsky, Ph.D. (Pittsburgh).

**Visiting assistant professor.** Linda M. Bambara, Ed.D. (Vanderbilt).

The department offers masters degrees and professional certification in Elementary and Secondary School Counseling, Community Counseling, Special Education and Social Restoration as well as the Ed.S. degree and professional certification in School Psychology. Ed.D. degree programs are offered in Counseling and Special Education and the Ph.D. degree is offered in Counseling Psychology, School Psychology, and Special Education. While general courses in the College are listed separately, the courses pertinent to each program are listed below.

## Department of Leadership, Instruction, and Technology

**Professors:** LeRoy J. Tuscher, Ph.D. (Florida State), *Chairperson;* Joseph P. Kender, Ed.D. (Pennsylvania); Robert L. Leight, Ed.D. (Lehigh); Herbert Rubenstein, Ph.D. (Columbia); Elvin G. Warfel, Ed.D (Columbia); Perry A. Zirkel, J.D. Ph.D. (Connecticut), LL.M. (Yale), *University Professor of Education and Law.*

**Associate professors:** Warren R. Heydenberk, Ed.D. (Colorado); Donald E. Langlois, Ed.D. (Columbia); Richard J. O'Connor, Ed.D. (Louisiana State); Saundra J. Tracy, Ph.D. (Purdue).

**Assistant professors:** Judith A. Bazler, Ed.D. (Montana); Francis A. Harvey, Ed.D. (Harvard); David S. Honeyman, Ph.D. (Virginia).

**Adjunct faculty:** Alfred J. Castaldi, Ed.D. (Pennsylvania); John M. Cipollini, Ph.D. (Pittsburgh); Charles W. Guditus, Ed.D. (Lehigh); Robert J. Kopecek, Ed.D. (SUNY Albany); John D. McAndrew, Ed.D. (Lehigh); James E. Morrell, Ed.D. (Lehigh); Thomas E. Persing, Ed.D. (Lehigh); Arthur L. Scott, Ed.D. (Lehigh); Hilary B. Shuard, M.A. (Oxford); David S. Snyder, Ed.D. (Lehigh); Karol Strelecki, M.Ed. (Lehigh); M. Jerry Weiss, Ed.D. (Columbia).

The department offers masters degrees and professional certification in Elementary and Secondary School Administration, Elementary and Secondary Education, Reading, as well as a master of science in Educational Technology. Ed.D. degree programs are offered in Administration, Educational Technology, Elementary Education, Foundations of Education and Reading. While general courses in the College are listed separately, the course offerings for each program are listed below.

## Education

**Educ 312. Classroom Practice (1-3)**
Experience in elementary and secondary classrooms as related to theories of child and adolescent development, classroom didactics, and philosophies of education. Problem-centered discussion and observations. Prerequisite: consent of the program director.

**Educ 313. Intern Teaching (3-6)**
Intensive practice in the application of the principles of teaching. Supervision is provided by the cooperating school and by the university. Prerequisite: consent of the program director.

**Educ 314. Seminar in Elementary and Secondary Education (1-3)**
Critical analysis and discussion of classroom instructional practices based on experiences of participants as they engage in teaching experiences. Prerequisite: consent of the program director.

**Educ 320. (Psyc 320) Psycholingustics (3)**
Study of the experimental and observational literature on psychological processes involved in the production, comprehension and use of language by adults.

**Educ 321. The Writing Process (3)**
Developmental characteristics of childrens' writing and relationships among writing, spelling and reading. Predictors of writing achievement, teaching strategies and activities, and evaluation schemes will be emphasized, K-12.

**Educ 330. Study of the Individual (3-6)**
Examinations of individual growth and development, especially the patterns found in different subcultures. Prerequisite: consent of the program director.

**Educ 341. The Teacher in Social Restoration (3-6)**
Functions of the teacher and the school in prevention and remediation of antisocial behavior. Field work in remedial teaching and experience in social restoration institutions. For social restoration interns only.

**Educ 343. The Disadvantaged Student (3)**
Philosophical analyses of disadvantagement and relevant educational theories. Applications and evaluations of special methods and techniques.

**Educ 351. Statistical Methods in Research (3)**
Methods of describing and condensing sample data and drawing

inferences about population characteristics. No background in statistics presumed. Emphasis on concepts.

**Educ 388. Computer Applications (3)**
Writing and testing computer programs; use and adaptation of packaged programs; applications in behavioral research, administration, and instruction. Prerequisite: Educ 408, or consent of the program director.

**Educ 391,2. Workshops (1-3)**
Cooperative study of current educational problems. Provides elementary, secondary, and special education teachers an opportunity to work at their own teaching levels and in their own fields. Limited to six credits during a summer session but the student may register for more than one workshop provided there is no duplication in subject matter.

**Educ 394. Special Topics in Education: (with subtitle) (3)**
Examination of a topic of research or professional interest in Education. Subtitle will vary. May be repeated for credit as Subtitle varies.

**Educ 400. Educational Psychology (3)**
An overview of learning theories, human growth and development, and the effect of selected educational practices upon the student. Attention is given to alternative strategies and processes of learning intervention.

**Educ 401. Sociological Foundations of Education (3)**
The American school as a social institution, its cultural heritage, its purposes and processes in relation to social change and educational leadership; its role in socialization and its responsibilities for relevance to social issues and to subcultural needs.

**Educ 402. Methods of Statistical Inference and Research Design (3)**
Introduction to packaged programs for computer analysis. Analysis of variance and covariance in experimental designs. Multiple correlation and regression. Prerequisite: Educ 351 or consent of program director.

**Educ 403. Research (3)**
Basic principles of research; techniques of gathering and analyzing data; design of studies in education. Emphasis on critical reviews of research reports representing various methodologies. Research report required.

**Educ 404. Introduction to Testing and Evaluation (3)**
Construction and evaluation of the teacher-made test. Selection of published tests and interpretation of individual and group results. Use and misuse of tests in assessing achievement.

**Educ 405. Comparative Education (3)**
Survey of educational practices abroad from nursery to graduate education. Systems of articulation, social foundations, legal foundations, and structure in government. Nature and purposes of the schools with reference to cultural patterns. Focus upon major problems and trends.

**Educ 406. Historical Foundations of Education (3)**
Development of primary, secondary, and higher education; aims, curricula, methods, and systems of schooling in America from colonial time to present, in relation to social conditions.

**Educ 407. Philosophical Foundations of Education (3)**
Comparative philosophical analysis of educational aims, practices, and institutions. Major philosophical theorists whose work has influenced educational thought.

**Educ 408. Statistics I (3)**
Data reduction, characteristics of frequency distributions, bivariate correlation and regression. Hypothesis testing, interval estimation, errors of inference, statistical power. Normal, t, F, and chi-square sampling distributions.

**Educ 409. Statistics II (3)**
One-way and factorial analysis of variance and covariance. Multiple correlation and regression, partial and part correlation. Use of packaged programs for computer analysis. Prerequisite: Educ 408 or consent of the program director.

**Educ 410. Statistics III (3)**
Analysis of variance and covariance in higher-order experimental designs including, factorial, incomplete factorial, nested, and repeated measures. Linear models approach. Prerequisite: consent of the program director.

**Educ 411. Multivariate Analysis (3)**
Multinormal sampling distribution. Multivariate tests of significance, interval estimation, analysis of variance and covariance. Discriminant analysis, canonical correlation, introduction to factor analysis. Prerequisite: Educ 410 or consent of the program director.

**Educ 412. Psychometric Theory (3)**
Theory of measurement applied to various kinds of tests and scales. Item analysis; pretesting, scaling and equating; errors of measurement; reliability and validity; prediction. Prerequisite: Educ 408 or consent of the program director.

**Educ 413. Intern Teaching (3-6)**
Intensive practice in the application of principles of teaching. Supervision is provided by the cooperating school and by the university. Prerequisite: consent of the program director.

**Educ 414. Intern Teaching Seminar (3)**
Critical analysis and discussion of classroom instructional practices. Discussion and illustration based on experience of participants as they engage in intern teaching. Prerequisite: consent of the program director.

**Educ 415. Classroom Didactics (3)**
Initial preparation of interns for classroom teaching. Secondary interns are trained in teaching methods in subject fields and the reading problems of secondary students. Elementary interns study teaching methods in the elementary school. Open to teaching interns only.

**Educ 416. (SR 416) Quasi-Experimentation and Program Evaluation (3)**
Social science research methods for non laboratory settings. Detailed examination of a dozen quasi-experimental research designs, three dozen threats to validity, possible controls, and uses in social program evaluation. Non-mathematical presentation.

**Educ 417. Participation in Teaching (3)**
Study, directed observation of, and initial practice in the various phases of teaching in a laboratory-demonstration school or in area elementary and secondary schools. Prerequisite: consent of the program director.

**Educ 418. Science in Elementary Education (3)**
Principles of the elementary science program. Demonstrations and discussions of appropriate materials and techniques for teaching science concepts to elementary school students.

**Educ 419. Mathematics in Elementary Education (3)**
Mathematical skills and concepts for the elementary school program. Sets, systems of numeration, experience with numbers, operations with numbers, number concepts and numerals, and elements of geometry.

**Educ 420. Linguistics in Education (3)**
The nature of language, phonetic applications and the relationships of linguistics to instruction in the language arts.

**Educ 421. Materials in Reading (3)**
Provides examination and critical analysis of published and unpublished reading materials used in instruction from kindergarten through adult levels. Prerequisite: Educ 426 or consent of the program director.

**Educ 422. Language Development of Children (3)**
The nature of language and its relation to the development of

communication skills. Critical analysis of related research. Implications for the elementary school.

**Educ 423. Social Studies in Elementary Education (3)**
Curriculum, content, teaching strategies, and instructional materials of the social studies field. Emphasis will be placed on organizing content, using appropriate methods, testing and evaluation, and innovations for social studies in the elementary school. Some attention will be given to examining textbooks, courses of study, and teacher-made materials.

**Educ 424. Developmental Reading (3)**
Introductory course spanning the elementary and secondary levels. Reading methods, materials, the disadvantaged and gifted reader, procedures for individualized reading instruction. Field experience required.

**Educ 425. Fine Arts in Elementary Education (3)**
Techniques for the infusion of concepts, skills and understandings from the creative arts into the elementary school program.

**Educ 426. Diagnosis and Adjustment of Reading Difficulties (3-6)**
Psychology of reading related to learning difficulties; measurement and diagnosis of reading difficulties; development of informal tests; materials for corrective and/or remedial instruction. Prerequisite: Educ 424 or consent of the program director.

**Educ 427. Children's Literature in Reading Instruction (3)**
Role of literature in the instructional program of the elementary schools. Use of trade books for individual instruction in reading.

**Educ 428. Reading in the Content Areas (3)**
Focuses on expository reading development in content areas such as language arts, mathematics, science and social studies. Practical teaching strategies in critical areas, such as comprehension and study skills. Review of research and methods for improving the reading development of students.

**Educ 429. Child Development (3)**
A study of physical, intellectual, emotional and social aspects of child development as they relate to the elementary schools.

**Educ 430. Advanced Topics in Reading (3)**
Theory and research in historical background of reading instruction; cognitive, affective, and linguistic aspects of reading; implications for the disadvantaged and gifted reader. Field experience required. Prerequisite: Educ 424 or consent of the program director.

**Educ 431. Critical Thinking in Reading (3)**
An understanding of the reading/thinking process and its relationship to logic, leading to the ability to analyze, criticize and advocate ideas and to reach factual or judgmental conclusions based on inferences drawn from the printed word. Implications and methods for teaching elementary through college level students will be addressed.

**Educ 432. Reading Specialists Clinic (6)**
Concentrates on diagnosis of reading problems and disabilities and the remediation of the deficits in children. Requires the graduate student to work with reading-disabled children for 125 clock hours.

**Educ 434. Seminar in Reading Research (3)**
An advanced course dealing with critical appraisal and discussion of classical and current studies in reading.

**Educ 435. Adult Literacy (3)**
The magnitude of illiteracy in the United States and its implications will be covered. Characteristics of the adult learner will be addressed as well as appropriate assessment strategies and instruments, methods of instruction, materials and programs. Program funding and development will be explored.

**Educ 436. Practicum in Supervision of Reading Program (3)**
For candidates for supervisor's certificate in reading. Organization of the instructional processes in reading programs. Participants in supervisory activities.

**Educ 438. Programs for Gifted and Talented (3)**
Characteristics of gifted children; teaching gifted children; programs for the gifted in elementary and secondary schools.

**Educ 441. Youth in Society (3)**
Social development, characteristics, and problems of adolescents and young adults. Impact of relationships with sibling, peers, adults, subcultures, in the context of changing institutions and values.

**Educ 450. Foundations of Curriculum Construction (3)**
Principles of organization of programs of studies for elementary and secondary schools; origin and background of the curriculum; methods of organization; curriculum planning and development; pertinent applications. K-12.

**Educ 451. (Psyc 451) Theories of Learning (3)**
In-depth study of major classical and contemporary learning theories. Review of experimental research relevant to theories.

**Educ 452. The Elementary School Curriculum (3)**
Problems of curriculum development in the first six grades; subject matter placement, program making for difficult types of schools, regular vs. special subjects, articulation.

**Educ 454. The Secondary School Curriculum (3)**
Methods of study of curriculum problems, selection of subject matter in various fields, principles of program construction, and similar problems.

**Educ 460. Program Evaluation (3)**
The historical background, theory, methodology, and current practices of program evaluation in the human services area. Emphasis will be placed on conducting evaluations of educational programs. Current research will be conducted and an examination of on-going program evaluations will be conducted.

**Educ 461. Single-Subject Research Design (3)**
Experimental designs for use with small N's. Topics include design theory and application, experimental validity (internal, external, statistical conclusions and construct validity) and an overview of data analysis procedures.

**Educ 474. (Psyc 474) Psychological Development in Childhood (3)**
Topics selected from such areas as socialization and the parent-child interaction, personality disorders in childhood, moral development and cognitive development. May be repeated for credit.

**Educ 491,2. Advanced Seminars: (with subtitle) (1-6)**
Intensive study and discussion of a specialized area. Title will vary. May be repeated for credit as title varies.

**Educ 493. Internship in: (with subtitle) (3)**
Opportunity for advanced students to obtain practical experience. Conference hours for students and staff members devoted to discussion of work and problems encountered in the schools. Prerequisite: consent of the program director.

**Educ 494. Field Work in: (with subtitle) (3)**
Identification of significant problems in an educational environment, review of the literature, and development of appropriate research plans.

**Educ 495. Independent Study in: (with subtitle) (1-6)**
Individual or small group study in the field of specialization. Approved and supervised by the major adviser. May be repeated.

**Educ 496. Doctoral Research Seminar (3)**
For doctoral students. Research design and application to various kinds of educational problems; data collection and analysis. Criticism and evaluation of student proposals. May be repeated for a maximum of nine credits.

## Administration and Supervision

### *For Graduate Students*

**AdmS 400. Educational Administration: Theory and Practice (3)**
Development of theories of administration and applications in educational institutions. Administrative behavior in organizational settings; administrator's leadership role in decision-making, evaluation, and conflict resolution.

**AdmS 402. Elementary School Administration (3)**
Major problems of organization and administration of elementary schools; types of organization, pupil promotion, time allotment, service agencies, and plant equipment.

**AdmS 404. Secondary School Administration (3)**
Major problems of organization and administration of secondary schools; program of studies, teaching staff, pupil personnel, plant and equipment, and community relationships.

**AdmS 406. School Principals Clinic (3-6)**
Simulated materials workshop on administrative decision-making open to practicing and prospective elementary and secondary school administrators.

**AdmS 410. Administration of Higher Education (3)**
Analysis of legal foundations, administrative controls, and operational patterns of various types of institutions of higher education.

**AdmS 411. Contemporary Issues in Administration (3)**
Analysis of the theoretical, empirical, and conceptual aspects of contemporary issues in educational administration and their implications for policy formulation and implementation in educational institutions. Prerequisite: Permission of the instructor.

**AdmS 412. Computer Applications in School Administration (3)**
Hands-on experience with computer applications useful in the administration of schools. Applications will include work processing, data base management, financial and demographic forecasting, resource allocation, graphical representation of data, and data retrieval and reporting systems useful for administrative decision making.

**AdmS 457. Performance Appraisal (3)**
Essential elements for the evaluation of school teachers, principals and superintendents. Research-based constructs as well as practical applications. The course is intended primarily for future and practicing school administrators.

**AdmS 466. Supervision of Instruction (3)**
Analysis of the principles underlying the organization and supervision of instruction; application to specific teaching situations. K-12

**AdmS 467. Management Seminar for Supervisors (3)**
A seminar on organization and management for first-line instructional supervisors. Covers four areas, including the legal aspects of supervision, budget development, evaluation, and organization behavior.

**AdmS 469. Advanced Instructional Supervision (3)**
A staff development approach to supervision designed to extend the supervisor's knowledge of and skills in applying clinical techniques to instructional supervision.

**AdmS 473. Personnel Administration (3)**
Overview of the personnel function in educational institutions. Trends in staff planning, recruitment, selection, assignment, and orientation, as well as tenure, grievances and related matters.

**AdmS 474. Planning for Facility Use (3)**
Focus on long-range planning with emphasis on data collection and analysis involved in closing, modifying and/or establishing alternative uses for school facilities. Simulations and field applications are provided.

**AdmS 476. School Finance (3)**
Concepts of school finance including intergovernmental fiscal relations, state grants-in-aid, taxation, municipal borrowing, and long-term capital outlay programs.

**AdmS 477. Seminar in School-Community Relations (3)**
Analysis and development of the communication and public relations skills needed by educators in dealing with the public.

**AdmS 478. Collective Bargaining in the Schools (3)**
Contract negotiations, grievance, mediation, and arbitration for both professional and classified employees in education.

**AdmS 479. School Law (3)**
Effect of school law on administration of public school systems; analysis and synthesis of judicial interpretations of the constitutions, statutes, rules, regulations, and common law relating to educational issues.

**AdmS 480. Administration of Student Service in Higher Education (3)**
Administration of student services in higher education including welfare, control, activities, and teaching functions. Organization and operation; administrator's role in development and implementation of appropriate policies.

**AdmS 481. Policy and Politics in Public Education (3)**
Analysis of the forces, factors, agencies, formal governmental systems and informal subsystems that influence educational policy in local districts and state and national governments.

## Counseling

**Coun 427. (SchP 427) Standardized Tests and Measurements (3)**
Principles of psychological measurements utilizing assessment techniques with focus upon standard group and individual tests. Administration and interpretation of tests.

**Coun 430. Philosophy and Principles of Counseling (3)**
Theoretical foundations, principles, and legal and ethical aspects of counseling. The organization, function, and services of a counseling program are examined. Accountability, counseling the culturally different, use of standardized tests, and other current issues are considered.

**Coun 433. Community Psychology (3)**
Community agencies are examined through readings, lectures and student presentations. Field investigation of a community counseling agency. Professional ethics, legal issues, accountability and organizational structure of agencies.

**Coun 436. Career Development (3)**
Examination of the career development process for children, adolescents, and adults. Study of theorists, vocational assessment process, and occupational and psychological information systems.

**Coun 439. Theory and Practice of Group Counseling (3)**
Introduction to the process of group counseling and therapy. Selection of group members; group rules; group procedures with children, adolescents and adults; ethical considerations with groups. Study of research on group processes, group therapy, and group leadership. Permission of the Instructor required.

**Coun 440. Introduction to Family Counseling (3)**
Research and current trends in the practice of family counseling. Overview and analysis of major theoretical approaches of family therapy.

**Coun 442. Counseling and Therapeutic Approaches (3)**
Introduction to theories and techniques of counseling and therapy. Students will practice therapeutic skills through role play and sessions with clients. Audio and video recordings required. Prerequisites: Coun 430 or Coun 433 or permission of instructor.

**Coun 445. Elementary School Counseling and Guidance (3)**
Emphasizes professional concerns of the elementary school counselor in working with teachers, parents, administrators, and other specialists. Policies, practices, and curriculum concerns, as they affect the development of the child. Prerequisite: Coun 430.

**Coun 448. Secondary School Counseling and Guidance (3)**
Establishing an effective secondary counseling and guidance program within the framework of the school setting. Policies, procedures, and curriculum concerns as they affect the student. Professional approaches to involve students, teachers, administrators, and parents in the counseling and guidance activities of the secondary school. Prerequisite: Coun 430.

**Coun 451. Group Counseling and Group Processes (3)**
Group processes as related to counseling and therapy through group participation and demonstration. Prerequisites: Coun 442 previously or concurrently; Coun 439.

**Coun 454. Biofeedback in Counseling (3)**
Theory and practice in biofeedback techniques; experience in using biofeedback instruments. Special attention is paid to relaxation procedures, anxiety reduction, and behavioral medicine. Prerequisite: Coun 442.

**Coun 457. (Psyc 473) Personality and Adjustment (3)**
Theories of personality and adjustment with emphasis on the adjustment processes in an educational setting. Prerequisite: consent of the program director.

**Coun 460. (Psyc 475) Theories of Psychological Counseling (3)**
Analysis and synthesis of concepts drawn from counseling theorists. Research and current trends in counseling concerning educational, social and vocational problems. Prerequisite: admission to the program in counseling.

**Coun 462. Assessment of Personality (3)**
Practice in the administration of instruments used for personality assessment. Supervised experience and report writing. Prerequisites: Educ 404 and SchP 422.

**Coun 466. Current Issues in Counseling and Therapy (1-6)**
Examination of an area of counseling or therapy that is of topical interest to students and faculty. Permission of program director required. May be repeated for credit.

**Coun 470. Independent Study and Research (1-6)**
Individual or small group study in the field of counseling. Approved and supervised by the major adviser. May be repeated for credit.

**Coun 471. Multi-Cultural Issues (3)**
This course will examine cultural influences on behavior. Historical and current perspectives on race, culture, and minority group issues in counseling and the broader discipline of psychology will also be explored.

**Coun 472. Human Development Across the Lifespan (3)**
An examination of prevailing theories of human growth and development across the lifespan. Examination of the interactive effect of various age groups upon one another. Particular emphasis on the helping relationships.

**Coun 473. Research Seminar in Counseling (1-3)**
For doctoral students in counseling. Research design, data collection, and data analysis. Criticism and evaluation of student proposals. May be repeated for a maximum of nine credits.

**Coun 474. Pre-Practicum I (3)**
Beginning counseling skills are taught using audio and video recordings. Supervision is provided in small groups. Prerequisite: permission of instructor.

**Coun 475. Pre-Practicum II (3)**
Counseling skills and key concepts are taught using audio and video recordings. Supervised experience in a counseling setting. Prerequisite: Coun 474.

**Coun 476. Supervision of Counseling (1-6)**
For candidates for supervisor's certificate or doctorate in counseling. Observation and supervision of counseling practicum students. Prerequisites: Coun 480 and permission of instructor.

**Coun 478. Advanced Group Leadership (1-6)**
Practicum training in group leadership in a counseling or therapeutic setting. Prerequisites: Coun 439, Coun 451, Coun 480 and permission of instructor.

**Coun 480. Practicum (1-4)**
Twenty hours of weekly supervised practicum training for advanced graduate students in individual, group, and family counseling and therapy. Prerequisites: Coun 442, Coun 451, Coun 475, and permission of instructor. May be repeated for credit.

**Coun 483. Field Work in Counseling (3-6)**
Identification of significant counseling and therapy related problems in an agency or institutional environment. Review of literature and development of appropriate research plans.

**Coun 486. Family Counseling Clinic (3-6)**
Supervised practicum training for advanced graduate students in family counseling and therapy. Techniques and methods of conducting family counseling and therapy. Prerequisites: Coun 480 and Coun 440.

**Coun 487. Advanced Practicum I (3)**
Supervised clinical experience for entry-level doctoral students. Emphasis on intake and assessment procedures. Audio and video recording, staffing, and individual and group supervision. Prerequisite: permission of the instructor.

**Coun 488. Advanced Practicum II (3)**
Supervised clinical supervision with emphasis on the development of intervention skills. Audio and video recording, staffing, and case presentations are required. Individual and group supervision. Prerequisite: Coun 487.

**Coun 489. Advanced Practicum III (6)**
Supervised experience in counseling and therapeutic settings for doctoral students. Use of audio and video recordings, small group supervision, and individual supervision. Permission of instructor. May be repeated for credit.

## Educational Technology

**EdT 311. (CSc 311) Instructional Programming in BASIC (3)**
Introduction to microcomputers and their applications in educational settings. Special emphasis on a structured approach to programming in the BASIC language and on application of principles of instructional design to the development of microcomputer-based instructional materials. No prior experience with microcomputers or programming is assumed. Departmental approval required.

**EdT 313. (CSc 11) Instructional Programming in PASCAL (3)**
PASCAL for microcomputers. High level, structured, procedure-oriented languages are examined. Special emphasis on use of structured programming for designing instructional software. Students electing EdT 313 are expected to complete the same course requirements as students taking CSc 11. In addition, they are required to become familiar with a microcomputer disk operating system. This is achieved through course assignments requiring the use of a microcomputer. The additional course requirements add an extra hour per week to the student workload.

**EdT 315. (CSc 230) Elementary Artificial Intelligence Applications (3)**
How computers play chess, compose music, create prose, simulate psychiatrists, and make medical diagnosis (an illustration of expert systems).

**EdT 331. Human Information Processing (3)**
Study of the processes involved in perception, learning, problem

solving and decision making. Applications of task analysis and artificial intelligence to the design of learning system.

**EdT 351. (CSc 351) Cognitive Science (3)**
A synthesis of elements of artificial intelligence, psychology and linguistics; concerned with models of the acquisition, representation, storage, retrieval and application of knowledge.

**EdT 415. Advanced Instructional Programming in BASIC (3)**
Advanced features of BASIC such as sequential and direct-access files, sorting, searching, modeling and simulation. Emphasis on applications in instructional settings. Prerequisite: EdT 311.

**EdT 417. (CSc 217) Advanced Instructional Programming in PASCAL (3)**
A continuation of structured programming in PASCAL. Special emphasis on the application of sound, color, and graphics in instructional courseware development. Prerequisite: EdT 313.

**EdT 419. (CSc 211) Computer Organization (3)**
Covers all aspects of programming microprocessors from basic concepts to advanced data structures. Additional topics will include hardware organization, instruction sets, addressing techniques, input/output devices, and application examples. Prerequisites: one high level programming language course (BASIC, FORTRAN, PASCAL, etc.) and consent of program director.

**EdT 420. Media Production for Instructional Programming (3)**
Applications in the design, production, editing, and evaluation of educational video tapes. Students will gain hands-on experience designing, filming, editing, and producing educational learning materials in a studio production center.

**EdT 421. Computer Literacy (3)**
An analysis of microcomputer applications designed for use in education and training. Special emphasis is placed on microcomputer applications. Hands-on experience in a microcomputer laboratory.

**EdT 423. Instructional Programming in LOGO (3)**
Hands-on experience with LOGO as a programming language and a philosophy of education. Study of turtle geometry procedures, recursion, words and lists, hierarchical structures, and interactive programming. Case studies of LOGO applications in various settings and with various computer systems.

**EdT 425. Learning, Technology and Society (3)**
A general survey of the impact of educational technology on modern society. Special attention to the use of large-scale data banks and retrieval systems, problems of privacy, impact of automation on everyday life, and effects of the new learning technologies on curriculum development and education configurations.

**EdT 427. Educational Technology and Instructional Games and Simulations (3)**
An examination of the motivational, technical, and instructional issues related to the design of microcomputer/video educational games and simulations. Course requirements will include designing and programming an instructional game or simulation. Prerequisite: EdT 429.

**EdT 429. Instructional Programming in Assembly Language (3)**
Translation of arithmetic and logical problems related to the use of sound, graphics, and animation into forms permitting their solution by microcomputers through assembly language programming. Emphasis on applications in instructional settings.

**EdT 433. Instructional Systems Design (3)**
The theory and process of developing and producing instructional units. Essentials for the production of instructional components that can be used directly in the development of microprocessor-controlled instructional units.

**EdT 435. Interactive Learning (3)**
Introduction to the utilization of interactive television, video-disc technology, *CD-ROM* and other high technologies for producing instructional software.

**EdT 436. Advanced Programming and Applications in Logo (3)**
Advanced programming in Logo, with special emphasis on interactive programs, recursion, and advanced use of lists (for example, association lists and manipulating programs as data). Analysis of current practices and issues related to Logo in education. Prerequisite: EdT 423 or equivalent.

**EdT 443. (CSc 343) Microcomputer-Aided Instruction (3)**
Design and development of microcomputer-assisted instructional units. Students design, program and test microcomputer-aided instructional units as a drill, practice, tutorial, and simulation exercises.

**EdT 471. Evaluation of Technology-Based Instructional Systems (3)**
Examination of current issues and practices related to the design and evaluation of instructional system with special consideration to the delivery and management of instruction utilizing educational technology. A case study approach will be used to study both Instructional Systems and the evaluation of individual learning in technology-based curricula.

**EdT 477. Research Topics in Educational Technology (3)**
Examination of current issues and practices related to the field of educational technology. Topics will vary (e.g., The Role of Educational Technology in Teaching Persons with Special Needs; The Role of Educational Technology in Teaching Preschool/ Nursery School Children; Educational Implications of Sound and Graphics. May be repeated for credit as topic varies.

## School Psychology

**SchP 402. (SpEd 402, Psyc 402) Applied Behavior Analysis (3)**
Theory and application of behavior modification methods in classroom and clinical settings. Topics include behavior analysis, outcome research, task utilization, and single case research.

**SchP 404. Historical and Contemporary Issues in School Psychology (3)**
History of Psychology, Education, and School Psychology. Roles and function of school psychologist; legal and ethical aspects of school psychology.

**SchP 405. (SpEd 405) Assessment of Mildly Handicapped Individuals (3)**
Educational assessment procedures used with exceptional individuals. Understanding and applying information from formal education assessment and interviews.

**SchP 412. Consultation Procedures (3)**
Observational methodology utilized in consultation; rationale, theory and methods of consultation; individual, group and parent consulting. Study of research on the consultation process.

**SchP 422. Assessment of Intelligence (3)**
Practice in the administration of individual tests of intelligence used in school evaluations and preparation of psychological reports. Prerequisite: permission of instructor.

**SchP 423. Behavioral Assessment (3)**
Techniques of behavioral assessment including, direct observation, interviews, checklists, rating scales, self-monitoring and role-play tests. Prerequisite: permission of instructor.

**SchP 425. Assessment and Intervention in Educational Consultation (3)**
Collection and use of data in designing classroom interventions. Curriculum based assessment, direct behavioral assessment, and structured interviews, and the interrelationship with diagnoses are emphasized within the behavioral consultation model. Utilization of data from actual case studies. Prerequisites: SchP 402, 423.

**SchP 426. Advanced Child Behavior Therapy (3)**
Techniques of child behavior therapy applied in classrooms and clinical settings. Particular emphasis on self-control procedures, such as social skills training, self-instruction training, and cognitive

behavior therapy. Course covers both the theoretical and practical components of procedures. Prerequisite: SchP 402.

**SchP 434. (SpEd 434) Applied Research Practicum (1-3)**
Designing and conducting research projects in applied settings.

**SchP 442. School Psychology Practicum (1-6)**
Experience in conducting assessments, designing interventions, and/or consultation. Taken in association with SchP 422, SchP 423, & SchP 425.

**SchP 443. Certification Internship (1-6)**
Full-time experience in clinical/educational settings. Student must complete a minimum of 1,600 clock hours under joint supervision of faculty and field supervisor. May be repeated for credit.

**SchP 444. Doctoral Internship (3-6)**
Full-time experience in clinical/educational settings. Student must complete a minimum of 1,600 clock hours under joint supervision of faculty and field supervisor. May be repeated for credit.

**SchP 496. Doctoral Seminar in School Psychology (with subtitle) (3)**
Selected topics in school psychology (titles will vary) including professional issues, assessment and intervention in school settings, and supervision of school psychology services. May be repeated for credit. Prerequisite: admission to doctoral program.

## Special Education

**SpEd 323. Programmatic Intervention with Students with Emotional/Behavioral Disorders (3)**
Theoretical and applied facts of structured treatment. Emphasis on the etiology and structure of the engineered classroom within a ReEducation model that promotes positive academic and social behaviors.

**SpEd 324. Introduction to Severe Handicaps (3)**
An intensive introduction to the applied behavior analysis procedures known as systematic instruction including task analysis, prompting, reinforcement, and positive procedures to manage problem behaviors. Overview of characteristics of individuals with severe handicaps (autism, cerebral palsy, mental retardation, multiple handicaps) and issues related to their education and habilitation.

**SpEd 330. Special Topics in Special Education: (with subtitle) (1-3)**
Current issues in the education of handicapped individuals. Titles vary. May be repeated for credit as title varies.

**SpEd 331. (Psyc 352) Emotional and Behavioral Disorders of Children (3)**
Definition, classification, etiology, treatment, and historical perspective of children and adolescent disorders.

**SpEd 332. Education of Exceptional Individuals (3)**
Legal, educational, and social issues related to the special education of people with mental retardation, physical handicaps, emotional/behavior disorders, learning disabilities, visual and hearing impairments, health impairments and those who are intellectually gifted.

**SpEd 333. Developmental Disabilities (3)**
Definition, classification, etiology, treatment and historical perspectives of individuals with mental retardation, autism,cerebral palsy, and other developmental disabilities (e.g., deaf/blind).

**SpEd 339. Learning Disabilities (3)**
Definition, classification, etiology, treatment, and historical perspective of individuals with learning disabilities.

**SpEd 402. (SchP 402, Psyc 402) Applied Behavior Analysis (3)**
Theory and application of behavior modification methods in classroom and clinical settings. Topics include behavior analysis, outcome research, task utilization, and single case research.

**SpEd 405. (SchP 405) Assessment of Mildly Handicapped Individuals (3)**
Educational assessment procedures used with exceptional individuals. Understanding and applying information from formal education assessment and interviews.

**SpEd 415. Physical Handicaps (3)**
Remediation of movement difficulties. Emphasis on teaching physically handicapped individuals.

**SpEd 417. Language and Social Skills (3)**
Empirically based strategies to teach skills in nonvocal communication, early language, conversational skills, grammar and other communication skills to individuals with mild or severe handicaps.

**SpEd 418. Teaching Severely Multihandicapped Individuals (3)**
Instructional emphasis upon areas of daily living and functional academics. Emphasis on training handicapped individuals to live in the least restrictive environment.

**SpEd 419. Teaching Mildly Handicapped Individuals (3)**
Instructional emphasis upon specialized curricula and methods for teaching typical school subjects. Emphasis on training handicapped individuals to learn in the least restrictive environment.

**SpEd 420. Intern Teaching: Certification (3)**
Competency based practice in application of procedures for teaching a broad spectrum of handicapped individuals in preparation for Level I Certification as a Teacher of the Mentally or Physically Handicapped. Prerequisite: consent of program coordinator one semester before registering for this course.

**SpEd 424. Assessment of Severely Handicapped Individuals (3)**
Curriculum based assessment and program development for individuals whose handicaps preclude traditional academic or psychological assessment. Emphasis on life skills assessment.

**SpEd 425. Specialization Internship (3)**
Competency based practice to develop specific expertise in Behavior Disorders, Severe/Multihandicaps, Curriculum Consultation or Special Education Technology. May be repeated for credit in more than one specialty. Prerequisite: consent of program coordinator one semester before registering.

**SpEd 428. Advanced Behavior Management for Severely Handicapped Individuals (3)**
This course will develop skills in long-term remediation of behavior problems characteristic of severely developmentally disabled individuals through functional analysis and management of variables influencing behavior.

**SpEd 430. Advanced Seminar in Special Education (3)**
Advanced issues relating to the field of special education. Titles will vary.

**SpEd 432. Supervision of Special Education (3)**
Advanced knowledge of teaching research with handicapped individuals. Teacher supervision models.

**SpEd 434. (SchP 434) Applied Research Practicum (1-3)**
Designing and conducting research projects in applied settings.

**SpEd 435. Internship: Supervision of Special Education (3)**
Advanced students receive competency based practice in staff supervision in preparation for certification as a Supervisor of Special Education. Prerequisite: consent of program coordinator one semester before registering for the course.

**SpEd 490. Doctoral Seminar in Special Education (3)**
Advanced knowledge of issues and research in the education of handicapped individuals. Topics will vary. May be repeated for credit. Prerequisite: admitted for doctoral studies.

# Educational Technology

See listings under Education.

# Electrical Engineering

See listings under Computer Science and Electrical Engineering.

# Electrical Engineering and Engineering Physics

This curriculum is particularly well suited for students seeking thorough preparation in the field of electronic device physics. The program adds to the basic electrical engineering curriculum a sequence of upper-level undergraduate physics courses.

The electrical engineering degree is conferred upon the completion of the fourth year (135 credit hours), and the engineering physics degree at the end of the fifth year (167 credit hours). Both are bachelor of science degrees. Interested students should contact Prof. G. J. Borse, department of physics, for information:

**freshman year in engineering** (see page 37)

**sophomore year, first semester** (17 credit hours)

| | |
|---|---|
| ECE 81 | Principles of Electrical Engineering (4) |
| CSc 33 | Principles of Computer Engineering (4) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |

**sophomore year, second semester** (17 credit hours)

| | |
|---|---|
| ECE 108 | Signals and Systems (4) |
| Math 205 | Linear Methods (3) |
| Phys 31 | Introduction to Quantum Mechanics (3) |
| Eco 1 | Economics (4) |
| | general studies (3) |

**junior year, first semester** (17 credit hours)

| | |
|---|---|
| ECE 123 | Electronic Circuits (3) |
| ECE 121 | Electronic Circuits Laboratory (2) |
| ECE 125 | Circuits and Systems (3) |
| Math 231 | Probability and Statistics (3) **or** |
| Math 309 | Theory of Probability (3) |
| Phys 212 | Electricity and Magnetism I (3) |
| | general studies (3) |

**junior year, second semester** (17 credit hours)

| | |
|---|---|
| ECE 126 | Physical Electronics (3) |
| ECE 136 | Electromechanics (3) |
| ECE 138 | Digital Systems Laboratory (2) |
| Phys 213 | Electricity and Magnetism II (3) |
| | mathematics elective (3) |
| | general studies (3) |

**senior year, first semester** (18 credit hours)

| | |
|---|---|
| ECE 111 | Proseminar (1) |
| ECE 151 | Senior Laboratory I (2) |
| Phys 215 | Classical Mechanics I (3) |
| | departmental elective (3) |
| | general studies (3) |
| | free electives (6) |

**senior year, second semester** (18 credit hours)

| | |
|---|---|
| Phys 362 | Atomic and Molecular Structure (3) |
| Phys 264 | Nuclear and Elementary Particle Physics (3) |
| ECE | departmental electives (9) |
| | general studies (3) |

**fifth year, first semester** (17 credit hours)

| | |
|---|---|
| Phys 216 | Classical Mechanics II (3) |
| Phys 273 | Research (2-3) **or** |
| Phys 260 | Laboratory Techniques (2) |
| Phys 340 | Thermal Physics (3) |
| Math 322 | Methods of Applied Analysis I (3) |
| | approved elective** (3) |
| | free elective (3) |

**fifth year, second semester** (15 credit hours)

| | |
|---|---|
| Phys 261 | Optics, Spectroscopy, and Quantum Physics Laboratory (2) |
| Phys 171 | Physics Proseminar (1) |
| | approved electives** (3) |
| | free electives (6) |

**Approved electives include two courses selected from Phys 363, 369, (352 or 355), and (346 or 348 or 365). Students planning graduate work in physics are advised to include Phys 273 and 369 among their electives.

# Engineering

Engr 1 is required of all engineering and applied science majors and is taken in the recommended freshman year.

**1. Engineering Computations (3)** fall-spring
Introduction to the solution of engineering problems through the use of the computer. Elementary computer programming in FORTRAN is taught and illustrated by means of several topics in computational mathematics such as roots of equations, matrices, least squares analysis, numerical integration, and others. No previous knowledge of computer programming is assumed. Also, a series of lectures and demonstrations are given, outlining the career opportunities available in the various disciplines represented in the College of Engineering and Applied Science. Prerequisite: Math 21 or 31, previously or concurrently.

**250. Computer Modeling of Scientific and Engineering Systems (3)**
Introduction to the mathematical modeling of scientific engineering systems, with emphasis on higher-order nonlinear models for which analytical methods are precluded. Solution of the model equations by computer-based numerical algorithms. Introduction to numerical methods for linear and nonlinear algebraic systems, ordinary and partial differential equations. Error analysis and control, stability and convergence in numerical calculations. Prerequisites: Engr 1; Math 205, previously or concurrently. Schiesser

# Engineering-M.B.A. Program

The bachelor in engineering-master of business administration two-degree program is designed to meet the needs of especially competent students in any engineering curriculum who want to add to their engineering studies training in business management at an advanced level.

The time involved will vary depending on the student's background. One or more summer sessions in addition to two or more regular semesters of study may be necessary after completion of the bachelor's degree in engineering to attain the M.B.A. or M.S. in management science. Candidates take the Graduate Management Admission Test and must meet the standards for admission into The Graduate School.

For background courses required for the master of business

administration program, engineering students should read Section IV, Graduate Study in Business and Economics, and consult with Joseph P. Klein, assistant dean of the College of Business and Economics.

# Engineering Mathematics

**Professors.** Philip A. Blythe, Ph.D. (Manchester, England) *head;* Dominic G. B. Edelen, Ph.D. (Johns Hopkins); Fazil Erdogan, Ph.D. (Lehigh); Stanley H. Johnson, Ph.D. (Berkeley); Arturs Kalnins, Ph.D. (Michigan); Alistair K. Macpherson, Ph.D. (Sydney); Kenneth N. Sawyers, Ph.D. (Brown); George C. M. Sih, Ph.D. (Lehigh); Gerald F. Smith, Ph.D. (Brown); Eric Varley, Ph.D. (Brown); J. David A. Walker, Ph.D. (Western Ontario).
**Associate Professors.** Terry J. Delph, Ph.D. (Stanford); D. Gary Harlow, Ph.D. (Cornell); Jacob Y. Kazakia, Ph.D. (Lehigh).

The *Division of Engineering Mathematics* was established within the Department of Mechanical Engineering and Mechanics to foster interdisciplinary research in the application of mathematics to the engineering and physical sciences. Interaction with industry is actively encouraged, and appropriate programs are designed for part-time students. Program content for all students is developed through close consultation with Division faculty.

For a description of the graduate programs in Applied Mathematics see the discussion under Interdisciplinary Graduate Programs on page 50 in Section IV. Engineering Mathematics courses are listed under Mechanical Engineering and Mechanics.

# English

**Professors.** Edward J. Gallagher, Ph.D. (Notre Dame), *chairperson;* Rosemarie A. Arbur, Ph.D. (Illinois); Peter G. Beidler, Ph.D. (Lehigh), *Lucy G. Moses Distinguished Professor;* Jack A. DeBellis, Ph.D. (U.C.L.A.); Jan S. Fergus, Ph.D. (C.U.N.Y.); James R. Frakes, Ph.D. (Pennsylvania), *Edmund W. Fairchild Professor of American Studies;* Albert E. Hartung, Ph.D. (Lehigh), *Distinguished Professor;* Frank S. Hook, Ph.D. (Yale); John W. Hunt, Ph.D. (Chicago); Rosemary J. Mundhenk, Ph.D. (U.C.L.A.); Barbara H. Traister, Ph.D. (Yale); John F. Vickrey, Ph.D. (Indiana).
**Associate professors.** Addison C. Bross, Ph.D. (Louisiana State); Elizabeth N. Fifer, Ph.D. (Michigan); Robert R. Harson, Ph.D. (Ohio).
**Assistant professors.** Alexander M. Doty, Ph.D. (Illinois); Edward E. Lotto, Ph.D. (Indiana), *head of The Learning Center.*

The Department of English offers majors in literature and minors in British literature, American literature, and Writing.

Courses in English language and literature may be considered a general preparation for any decent kind of living. These courses require close attention to words and at the same time encourage that loving respect for the true naming of things, which is the source of all clear and honest thought.

In literature itself, which is words that we wish to hear again and yet again, we may find a happy companionship with minds that can help our own grow straight with grace and understanding. A head that is full of poetry is a good one to live with.

## *Undergraduate Major in English*

The major in English is designed to give interested students experience in reading, analyzing, and formulating thoughts about what Matthew Arnold called "the best that has been thought and said"; an understanding of how literary artists find the appropriate words to express their thoughts and feelings; and a basic knowledge of the historical development of British and American literature.

Students who major in English often go on to careers in teaching, writing, law, or business, but the analytical and communication skills acquired in the study of literature and writing will be of use in almost any profession or human activity. Depending on their interests, abilities, and career plans, students who major in English are encouraged to consider double majors or minors in other fields. The major in English is flexible enough to allow cross-disciplinary study with ease.

The student majoring in English has considerable freedom to choose from an extensive list of courses. To insure breadth of coverage, each major is required to take Engl 25 and 26, British Literature, and Engl 23, American Literature, first semester. These three courses are designed to acquaint the student with the important British and American writers, and with certain movements and trends in literature before the twentieth century.

To insure depth of understanding of at least two basic early writers, each English major is required to take either Engl 329 or 330, Shakespeare and Elizabethan Drama, and either Engl 327, Chaucer, or Engl 331, Milton. In addition to these five courses, each English major elects five additional courses in either English or American literature, at least two of which are in literature before 1900 and at least three of which are numbered above 300. With the exception of Engl 348 and 263, writing and film courses are not included in the major program.

It should be emphasized that thirty is the *minimum* number of credit hours for the major; many English majors will elect to take more. Each English major has a departmental adviser to assist in selecting courses for the major program.

The department strongly recommends that any student contemplating the possibility of advanced study of English or American literature or of becoming a teacher of English should work toward departmental honors.

In order to receive departmental honors the English major must attain a 3.50 grade average in courses presented for the major and must complete 39 credit hours of course work in English. Fifteen of these hours (five courses) are those required for the regular English major: Engl 23, 25 and 26, Engl 329 or 330, and Engl 327 or 331. Twelve hours (four courses) should be chosen from among the department's advanced period courses (Engl 360, 362, 364, 367, 369, 371, 376, 372, 377, 378, 379, 380, 385 and 386), at least two of which must be in literature before 1900; three or six hours (English 181 and 182) are in the form of a thesis of substantial length (normally 25 to 50 pages).

The department also recommends that students working for departmental honors elect Engl 248, Introduction to the English Language; that they develop a competency in at least one foreign language; and that they consider petitioning in their senior year to take one of the department's graduate seminars at the 400 level. Students who complete the courses required for departmental honors but who do not achieve the necessary grade-point average will receive the bachelor of arts degree with a major in English.

## *Minors in English*

The Department of English offers three minors, each requiring fifteen hours of course work beyond freshman English.

To minor in British Literature, a student takes Engl 25 and 26, British Literature, and an additional nine hours in British literature, at least six of them in British literature at the 300 level.

To minor in American Literature, a student takes Engl 23 and 24, American Literature, and an additional nine hours in American literature, at least six of them in American literature at the 300 level.

To minor in writing, a student takes Engl 171, Practical Writing, and Engl 348, Theory and Practice of Writing, and nine hours chosen from Engl 173, 172, 173, Engl 201, 248, Journ 11, Journ 12, Journ 123, or any literature course designated Writing Intensive (WI).

The student's major adviser monitors the minor program, but the student must consult the minor adviser in the Department of English when setting up a minor program.

## *Graduate Work in English*

The objective of the graduate program in English is not simply to impart knowledge, however wide or deep, but also to instruct the student in the methods of pursuing advanced study of literature and

to provide training in the techniques of criticism and research, and in pedagogical approaches to literature.

A primary aim of the program is to furnish course work and individual instruction suitable for teachers of English at the secondary and college levels. Advanced degrees may be obtained in all areas of English and American literature.

Students who wish to enter the graduate program in English should have an undergraduate major in English with at least fifteen credit hours of advanced courses in English literature. Students who did not major in English may be admitted, but will be expected to make up deficiencies in their undergraduate training in English in addition to satisfying other minimum requirements for the graduate degree sought.

Candidates for the master's degrees in English who expect to continue for the doctor of philosophy degree are required to complete successfully twenty-seven credit hours of course work and to write a thesis representing the equivalent of three hours of course work. Master's degree candidates who do not wish to continue for the Ph.D. may, as an alternative, complete successfully twenty-seven hours of course work and pass an examination, preparation for which represents the equivalent of three hours of course work (see Engl 492). Details concerning the examination are available from the graduate program coordinator.

Candidates for the master's degree whose needs and interests make it desirable may substitute up to six hours of collateral work in other departments. Master's candidates must take at least six of their required courses (including thesis) at the 400-level, but may select the balance of their curriculum from a variety of 300-level course offerings. At least six hours of course work for the master's degree should be in literature before 1660.

Candidates for the doctor's degree are accepted only after a consultation with the graduate committee concerning the candidate's qualifications. Each candidate is required to take at least one course from the following sequence: Engl 421, History of the English Language; Engl 423, Old English; and Engl 424, Beowulf.

The foreign language requirement for the doctor of philosophy (usually in Latin, French or German) may be satisfied in one of two ways: 1. the demonstration, through examination, of a reading knowledge of two foreign languages; or 2. the successful completion, concurrent with the graduate program, of a foreign language course, to be approved by the departmental director of graduate studies, at the 200, 300, or 400 level (or at a lower level in classical languages).

For the doctoral examination each candidate selects the following to be examined upon:

1. One of the following traditional periods: Old English and Medieval; Renaissance and Jacobean, 1500-1660; Restoration and Eighteenth century, 1660-1798; Romantic and Victorian, 1798-1900; American Literature, Colonial-1900; Modern British Literature, 1900-present; Modern American Literature, 1900-present.

2. A major figure, to be selected in consultation with the director of graduate studies and subject to the approval of the departmental graduate committee.

3. A genre, theme, matter, or customary grouping, to be selected in consultation with the director of graduate studies and subject to the approval of the departmental graduate committee.

In each of the three areas of the examination, the candidate is expected to demonstrate the knowledge and expertise that would be necessary to teach a course in the subject. The three areas may not overlap except for, in rare instances, the third.

## *Freshman Composition Requirement*

With the two exceptions noted below, all undergraduate students take six credit hours of freshman English courses: English 1 and one of the five options for the second semester, Engl 2, 4, 6, 8, 10. The exceptions are:

1. Advanced placement and six hours of Lehigh credit for freshman English are given to students who earn a score of 5 on the College Board Advanced Placement Test in English. These students need not take the regular freshman English courses (English 1, 2, 4, 6, 8, 10), but they are encouraged to elect Engl 11 and 12, seminars designed to give advanced freshman practice in reading and writing at the college level. Students who receive a grade of 4 on the Advanced Placement Test in English or who have a score of 700 or higher on the SAT Verbal Aptitude Test will receive three hours of credit in freshman English; these students will complete the six-hour requirement by taking Engl 2, 4, 6, 8, 10, 11, 12 or 171. Students in this category should seek advice from the department about which courses to roster. Students who have an SAT Verbal Aptitude Test score between 650 and 699 and who have received a grade of 3 on the College board Advanced Placement Test in English may apply to the department for an anticipatory or special examination which, if completed successfully, will result in three hours of credit and exemption from Engl 1.

2. Students with English as a Second Language. Categories include students on non-immigrant visas, students on immigrant visas, registered aliens, and citizens either by birth or by naturalization.

Students in all these categories for whom English is not the first language may petition for special instruction through the program in English as a Second Language.

At matriculation, all foreign students take an English-language competence test to determine the kind of instruction best suited to their needs. Matriculating freshmen judged to be qualified will roster Engl 1, followed by Engl 2, 4, 6, 8, or 10. Others will be enrolled in Engl 3, followed by Engl 5 (or 2, 4, 6, 8, or 10).

Students enrolled in the English as a Second Language program are expected to reach a level of competence comparable to those in the usual freshman program. The form of instruction, however, will differ in the ESL program by taking into account the special problems of non-native speakers.

Matriculating students in all the above categories who are entering at a level above the freshman year, but who need composition credit, should consult the department for advice.

## Freshman Courses

**1. Composition and Literature (3)**
The art of expository writing. Appropriate collateral reading.

**2. Composition and Literature: Fiction, Drama, Poetry (3)**
Continuation of Engl 1. Further practice in expository writing in conjunction with the study of fiction, drama, and poetry.
Prerequisite: Engl 1.

**3. English as a Second Language (3)**
Idiomatic English both oral and written, with a strong emphasis on producing well-organized, coherent essays. Enrollment limited to non-native speakers; placement is determined after testing by the Department of English.

**4. Composition and Literature: The Novel (3)** spring
Continuation of Engl 1. Further practice in expository writing in conjunction with study of selected novels. Prerequisite: Engl 1.

**5. English as Second Language II (3)**
Continuation of English 3.

**6. Composition and Literature: Drama (3)** spring
Continuation of Engl 1. Further practice in expository writing in conjunction with the study of literary and theatrical aspects of several classic and contemporary plays. Prerequisite: Engl 1.

**8. Composition and Film Study (3)** spring
Continuation of Engl 1. Further practice in expository writing in conjunction with the study of film. Prerequisite: Engl 1.

**10. Composition and Literature: Fiction (3)** spring
Continuation of Engl 1. Further practice in expository writing in conjunction with the study of short stories, novellas, and novels.
Prerequisite: Engl 1.

**11. Literature Seminar for Freshmen (3)** fall
Discussion of and writing about selected masterworks of literature. Open as an elective to any freshman exempt from the regular freshman English requirement.

**12. Literature Seminar for Freshmen (3)** spring
Discussion of and writing about selected masterworks of literature. Open as an elective to any freshman exempt from the regular

freshman English requirement. After passing Engl 1, students judged to be qualified may complete the English composition requirement by taking this course instead of Engl 2, 4, 6, 8, or 10.

## Basic Undergraduate Courses

The following courses are open to any student who has completed, or who is exempt from, the required six hours of freshman English. Students may roster one of the following as a second English course to be taken concurrently with Engl 2, 4, 6, 8, or 10, if they have earned a grade of B or above in Engl 1.

**23. American Literature I (3)**
Significant American writing from the settlement through the middle of the 19th century. Prerequisite: six hours of freshman English.

**24. American Literature II (3)**
American literature from the middle of the 19th century to the present. Prerequisite: six hours of freshman English.

**25. British Literature I (3)**
British literature from Beowulf through the Pre-Romantics. Prerequisite: six hours of freshman English.

**26. British Literature II (3)**
British literature from Wordsworth to Auden. Prerequisite: six hours of freshman English.

**53. The Short Story (3)**
English, American, and continental short story. Class discussions, collateral reading, and reports. Prerequisite: six hours of freshman English.

**59. World Literature (3)**
Great works from the literature of epic poetry, drama, romance, and essay that illustrate the humanistic traditions of Western civilization. Prerequisite: six hours of freshman English.

**63. Narrative Film (3)**
History and aesthetics of narrative film. May be repeated for credit as title varies. Prerequisite: six hours of freshman English. Doty

**72. Words (1-3)**
Improving vocabulary, spelling, and diction through study of word formation, etymology, prefixes, suffixes. Students rostering one credit hour will complete programmed texts emphasizing morphology and etymology. Additional credit hours added for study emphasizing denotation and connotation in literary contexts and for independent study requiring a paper.

**73. Creative Writing Workshop (3)**
Practice in and classroom criticism of creative writing done by students taking the course. Title may vary: Short Story; Drama; Poetry; etc. May be repeated for credit. Prerequisite: six hours of freshman English.

**74. Editing the Manuscript (1)**
How to improve your papers by editing: spelling, punctuation, proper usage, and correct grammar.

**85. Performing Literature (1-3)**
Study of and practice in literature to be performed before an audience. Title will vary. May be repeated for credit as title varies.

**89. Science Fiction (3)**
From 'hard SF' to high fantasy. The fusing of aesthetic, philosophical, scientific and technological orientations in the literature of our post-atomic culture. Prerequisite: six hours of freshman English. Arbur

**91. Special Topics (1-3)**
A topic, genre, or approach in literature or writing not covered in other courses.

## Upperclass Undergraduate Courses

The following courses are more advanced than the courses that appear in the preceding list, but they are by no means designed exclusively for specialized students. Each course is a self-contained unit and has no prerequisites beyond the two semesters of freshman English.

The purpose of most of the courses listed below is to acquaint students from all segments of the university with the best that has been written through the ages by the most effective literary artists. *These courses may be used to fulfill preliminary or upperclass distribution requirements for students in the College of Arts and Science.*

**119. Literature and Technology (3)**
Reflections of and reactions to technological progress by major writers of the 18th, 19th and 20th centuries, such as Swift, Dickens, Twain, and Vonnegut. Prerequisite: six hours of freshman English. Gallagher

**129. Shakespeare and Elizabethan Drama (3) fall**
Study of the earlier plays of Shakespeare, mostly comedies and histories. Selected plays from contemporary dramatists such as Marlowe, Greene, and Jonson. Meets with Engl 329, but has a reduced reading and written assignment load. Prerequisite: six hours of freshman English. Traister

**130. Shakespeare and Elizabethan Drama (3) spring**
Study of the later plays of Shakespeare, the tragedies and romances. Selected plays from contemporary dramatists such as Webster, Tourneur, Middleton. Meets with Engl 330, but has a reduced reading and written assignment load. Prerequisite: six hours of freshman English. Traister

**151. The Drama (3)**
Selected plays; theories of drama; drama and the stage. Prerequisite: six hours of freshman English.

**155. The Novel (3)**
Selected novels as works of literature. Prerequisite: six hours of freshman English.

**157. Poetry (3)**
Traditional and modern poetry read for pleasure and understanding. Prerequisite: six hours of freshman English.

**171. Practical Writing (3)**
Practice in and criticism of expository writing beyond the freshman level. Prerequisite: six hours of freshman English.

**172. Practical Writing II (1-3)**
Continuation of Engl 171. Prerequisite: Engl 171.

**173. Personal Writing (3)**
Practice in writing from immediate experience, with emphasis on accurate, persuasive descriptive writing.

**175. Individual Authors (1-3)**
Intensive study of the works of one or more literary artists. Title will vary: Hemingway; Tolkien. May be repeated for credit as title varies. Prerequisite: six hours of freshman English.

**177. Individual Works (1-3)**
Intensive study of one or more literary works. Title will vary: Moby Dick; Stories of John Cheever. May be repeated for credit as title varies. Prerequisite: six hours of freshman English.

**179. Character Types in Literature (1-3)**
Study of a character type in several works of literature by several authors. Title will vary: The Scientist in Drama and Fiction; The Magician in Literature. May be repeated for credit as the title varies. Prerequisite: six hours of freshman English.

**181. Undergraduate Thesis (3)**
Open to advanced undergraduates who wish to submit theses in English. Prerequisite: consent of the department chairperson.

**182. Undergraduate Thesis (3)**
Open to advanced undergraduates who wish to submit theses in English. Prerequisite: consent of department chairperson.

**183. Readings in English and American Literature (3)**
Open to advanced students who wish to pursue special or independent courses of reading in literary study. Prerequisite: consent of the department chairperson.

**187. Themes in Literature (1-3)**
Study of a recurring theme as it appears in several works of literature. Title will vary: Utopian Literature; Censorship and Literature. May be repeated for credit as title varies. Prerequisite: six hours of freshman English.

**189. Popular Literature (1-3)**
A form of literature that is or has been of interest primarily to a 'popular' audience. Title will vary: Folklore; Detective Fiction. May be repeated for credit as title varies. Prerequisite: six hours of freshman English.

**191. Special Topics (1-3)**
A topic, genre, or approach in literature or writing not covered in other courses. Prerequisite: six hours of freshman English.

**201. Special Topics in Writing (1-3)**
Approaches not covered in other writing courses. Individual projects. May be repeated for credit. Prerequisite: Engl 171, or consent of department chair.

**248. Introduction to the English Language (3)**
Basic linguistic concepts together with a historical survey of the English language. Vickrey

**263. Film History and Criticism (3)**
Study of certain films, dealing with a particular genre, director, theory, period or theme. May be repeated for credit as title varies. Doty

**281. Internship (3)**
Projects on or off campus in business, professional, or government organizations. Projects approved by department committee on internships and supervised by department internship adviser. Project includes extensive writing that can be submitted for evaluation. Enrollment limited to juniors or seniors with a major or minor in English. Prerequisite: consent of department chair. Harson

**291. Special Topics (1-3)**
A topic, genre, or approach in literature or writing not covered in other courses.

**301. Topics in Literature (1-3)**
A theme, topic, or genre in literature. Title will vary: Autobiography as Literature; British Drama. May be repeated for credit as title varies.

**311. Literature of Women (3)**
Women's works about women: is literary creativity gender-identified? Are there specifically "feminine" subjects or themes? Besides re-reading some familiar fiction, drama, and poems, introduction to contemporary and often experimental works by less famous writers. Arbur

**312. Jewish Literature (3)**
Development of Jewish literature (including Yiddish literature in translation) from Russian and Eastern European beginnings to immigration and assimilation in America. Fifer

**316. The Indian in American Literature (3)**
The American Indian as portrayed in folklore, poetry, and fiction in America. Works written by both Indian and non-Indian writers. Beidler

**327. Chaucer (3)**
The chief works of Geoffrey Chaucer, with attention to his language and the backgrounds of his works. Beidler

**329. Shakespeare and Elizabethan Drama (3)** fall
Study of the earlier plays of Shakespeare, mostly comedies and histories. Selected plays from contemporary dramatists such as Marlowe, Greene, and Jonson. Traister

**330. Shakespeare and Elizabethan Drama (3)** spring
Study of the later plays of Shakespeare, the tragedies and romances. Selected plays from contemporary dramatists such as Webster, Tourneur, Middleton. Traister

**331. Milton (3)**
Life and works of John Milton in connection with the history of his times and the chief sources of his inspiration.

**348. Theory and Practice of Writing (3)**
Approaches to writing, ancient to modern; practice in composition. Theory and practice to help students develop strategies for writing effectively. Lotto

**356. The Novel (3)**
The novel as a literary form; selected novels from England, America, and the continent. Emphasis on a theme, period, or type.

**360. Middle English Literature (3)**
Major literary works of the Middle English period by authors other than Chaucer. Emphasis on Piers Plowman, the Gawain/Pearl Poet, and the metrical romances. Hartung

**362. The Renaissance (3)**
English nondramatic literature in the 16th century and the stimulus of the Italian Renaissance and northern humanism. Readings in and class discussions of the works of the chief writers: Petrarch, Erasmus, More, Wyatt, Surrey, Lyly, Sidney, and Spenser.

**364. The Seventeenth Century (3)**
English literature of the 17th century, from Donne to Dryden. Traister

**367. The Eighteenth Century (3)**
Great British writers of the 18th century, beginning with the Restoration: Dryden, Pope, Swift, Defoe, Fielding, and Johnson and his circle. Fergus

**369. British Romantic Literature (3)**
Poetry and prose of Wordsworth, Coleridge, Byron, Shelley, and Keats within the contemporary, political, religious, and social context. Harson

**371. British Victorian Literature (3)**
Poetry and prose of Tennyson, Browning, Arnold, Swinburne, Carlyle, Mill, Newman, and Ruskin within the contemporary political, religious, and social context. Bross

**372. British Victorian Fiction (3)**
Major fiction of the Victorian era by such writers as Dickens, Eliot, Thackeray, and Hardy within historical, social, and aesthetic contexts. Mundhenk

**375. Major Authors (1-3)**
The works of one or more major literary figures studied in depth. May be repeated for credit as title varies.

**376. Early American Literature (3)**
Beginnings of American Literature, from Puritanism through the Enlightenment to early Romanticism: Taylor, Edwards, Franklin, Irving, Cooper. Gallagher

**377. American Romanticism (3)**
The chief American Romantics: Emerson, Thoreau, Whitman, Hawthorne, Melville, and Dickinson. The European and American philosophical, historical, and social background as well as the aesthetic study of romantic masterpieces. Arbur, DeBellis

**378. American Realism (3)**
Theory and practice of realistic fiction from the Civil War to the

early 20th century: Twain, Howells, James, Norris, Crane, Dreiser, and others. Frakes

**379. Twentieth-Century American Literature (3)**
American literature before World War II. Lectures and class discussion of major fiction and poetry. DeBellis, Mundhenk

**380. Contemporary American Literature (3)**
American literature since World War II. Lectures and class discussions of new writers and of recent works of established writers. DeBellis, Frakes

**382. Themes in American Literature (3)**
Intensive study of one topic in American literature. Readings from the colonial period to the present. May be repeated for credit as title varies.

**383. Modernism and Post-Modernism in Fiction (3)**
The 'anti-realistic' novel; time/space, point of view, narrative voice, structure as meaning. Kafka, Woolf, Beckett, Nabokov, Robbe-Grillet, Faulkner, Borges, Hawkes, Stein. Frakes

**385. Twentieth-Century World Literature (3)**
World English literature and continental literature before World War II. Lectures and class discussion of major fiction and poetry. Frakes

**386. Contemporary World Literature (3)**
World English literature and continental literature since World War II. Lectures and class discussions of new writers and of recent works by established writers. Frakes, Fifer

**388. Independent Study (1-3)**
Individually supervised study of a topic in literature, film, or writing not covered in regularly listed courses. Prerequisite: consent of department chairperson.

**391. Special Topics (1-3)**
A topic, genre, or approach in literature or writing not covered in other courses.

## Graduate Courses in English

The following courses are seminars, ordinarily limited to no more than twelve graduate students, but undergraduate English majors who are planning to go on to graduate school in English and who have shown proficiency in the study of literature may petition to take one of these seminars in their senior year.

**421. History of the English Language (3)**
The phonology, grammar, and lexicon of English from the beginnings to the present. Vickrey

**423. Old English (3)**
Old English language and literature. Vickrey

**424. Beowulf (3)**
The Beowulf poem and some of the pertinent scholarship. Vickrey

**427. Chaucer (3)**
Chaucer's language. The Canterbury Tales. Readings, reports, and discussions. Hartung

**428. Chaucer (3)**
Chaucer's Minor Poems, Troilus and other pre-Canterbury period works.The 15th-century 'Chaucerians.' Readings, reports, and discussions. Hartung

**429. Middle English Metrical Romances (3)**
Non-Arthurian verse romances. Introduction to paleography. Folk and court backgrounds. Narrative theory. Hartung

**431. Arthurian Literature of the Middle Ages (3)**
Arthurian literature from its Celtic Beginnings to Malory's *Morte D'Arthur.* Hartung

**433. Middle English Literature (3)**
A topic, a genre, or a grouping of works or authors in the Middle English period. Sample offerings: The Medieval Comic Tale; Medieval Drama. May be repeated for credit as title varies. Beidler

**439. Sixteenth-Century British Literature (3)**
A topic, a genre, or a grouping of works or authors in the 16th century. Sample offerings: 16th Century Drama; Spenser. May be repeated for credit as title varies. Traister

**441. Seventeenth-Century british Literature (3)**
A topic, a genre, or a grouping of works or authors in the 17th century. Sample offerings: Jacobean and Caroline Drama; Metaphysical Poetry. May be repeated for credit as title varies. Traister

**443. Eighteenth-Century British Literature (3)**
A topic, a genre, or a grouping of works or authors in the 18th century. Sample offerings: The Rise of the Novel; Boswell, Johnson, and Their Circle. May be repeated for credit as title varies. Fergus

**445. Nineteenth-Century British Literature (3)**
A topic, a genre, or a grouping of works or authors in the Romantic or Victorian periods. Sample offerings: Wordsworth and Byron; The Victorian Novel. May be repeated for credit as title varies. Bross, Harson, Mundhenk

**449. Twentieth-Century British Literature (3)**
A topic, a genre, or a grouping of works or authors in 20th century literature of the British Isles. Sample offerings: Conrad; Joyce. May be repeated for credit as title varies. Frakes, Bross

**471. Early American Literature (3)**
A topic, a genre, or a grouping of works or authors of colonial America or the early republic. Sample offerings: The Roots of the American Dream; Science and Religion in the Colonial Period. May be repeated for credit as title varies. Gallagher

**473. American Romanticism (3)**
A topic, a genre, or a grouping of works or authors in the American Romantic period. Sample offerings: The Nature of Evil in Hawthorne; Melville and Poe. May be repeated for credit as title varies. Arbur, DeBellis

**475. American Realism (3)**
A topic, a genre, or a grouping of works or authors in American literature from the Civil War to World War I. Sample offerings: James; American Literary Naturalism. May be repeated for credit as title varies. Frakes

**477. Modern American Literature (3)**
A topic, a genre, or a grouping of works or authors in the literature written after World War I. Sample offerings: Hemingway and Faulkner; Southern Writers. May be repeated for credit as title varies. DeBellis, Frakes

**481. Literary Criticism (3)**
Theory and practice of criticism. The nature and function of literature itself, the assumptions and methodologies of major 20th century critical 'schools,' and similar topics, regarded as objects of knowledge and as models for students' own critical reading, writing, and teaching. May be repeated for credit as title varies. Arbur

**485. Teaching of College English (3)**
History, theory, and practice of teaching the freshman composition course. Required of all new teaching assistants in the department of English. May be rostered by others only with consent of the department chairperson.

**489. Workshop for English Teachers (1-3)**
Study of a body of information with particular emphasis, through reports and discussion, on how the information can best be taught to secondary and college students. Sample offerings: Shakespeare for Teachers; Teaching the Novel; Teaching Poetry. May be repeated for credit as title varies.

**491. Special Topics (1-3)**
A topic, genre, or approach in literature or writing not covered in other courses. May be repeated for credit as title varies. Prerequisite: consent of the graduate program coordinator.

**492. Supervised Reading (3)**
Individually supervised study for candidates for master of arts degrees who desire to take examinations on selected figures rather than to submit theses. Prerequisite: consent of graduate program coordinator.

**493. Graduate Seminar (3)**
Intensive study of the works of one or more authors, or of a type of literature, or of the teaching of an author or a type of literature. May be repeated for credit as title varies.

**495. Independent Study (3)**
Individually supervised course in an area of literature, film, or writing not covered in regularly listed courses. Prerequisite: consent of the graduate program coordinator.

# Environmental Sciences and Resource Management

Edward B. Evenson, Ph.D. (Michigan), *director,* professor of geological sciences.

Concentration advisers. David L. Cundall, Ph.D. (Arkansas), *biology;* Robert S. Sprague, Ph.D. (Illinois), *chemistry;* Sharon M. Friedman, M.A. (Penn State), *environmental science writing;* Edward B. Evenson, Ph.D. (Michigan), *geology.*

Society's increasing demands for energy, water, mineral commodities, food, recreational and living space have altered and will continue to alter the global ecosystem. The need for personnel trained to evaluate proposed alterations and to repair existing deleterious or critical situations can best be met by an interdisciplinary approach. Additionally, there is pressing need to communicate about environmental problems at all levels of society, from the scientist to the layman. Writing about the environment can best be done by persons trained in both science and communication skills.

Environmental sciences and resource management is an interdepartmental major fostering basic preparation for advanced study or an immediate career in environmental management, conservation and environmental science writing. The backgrounds of fundamental mathematics and science required to understand the interactions of humans and their environment are established early in the major where the student is exposed to the core courses of mathematics, chemistry, physics, biology and geology.

Following this basic preparation, students select a concentration area within which more advanced training is undertaken. Concentrations in biology, chemistry, geology and environmental science writing have been established and concentrations in other fields can be designed to meet the needs and career desires of individual students.

Student research, work experience, and internships involving laboratory, field, library or mass media research is an integral part of the program and is strongly encouraged.

Graduates of this major can expect to take part in planning, education, research and coordination of environmental programs for all levels of government and industry. Those concentrating in environmental science writing also can pursue careers in science journalism or in professions such as environmental law or environmental management, where communication skills are highly desired. Graduate study is advisable for students wishing to pursue a career in most aspects of environmental science and the program provides thorough preparation for advanced training in environmental science or concentration areas.

## B.S. in Environmental Sciences and Resource Management

### *Major Requirements*

The program requires 120 credit hours. Credit is allocated as follows: 37 credits for college and university requirements, 65 credits in required preliminary courses, and 18 credit hours in the area of concentration.

**college and university requirements** (37 credit hours)

| | |
|---|---|
| Arts and Science 1 | Choices & Decisions (1) |
| Engl 1 | Composition and Literature (3) |
| Engl 2, 4, 6, 8, 10 or 16 | Composition and Literature: Fiction, Drama, Poetry (3) |
| | general electives (30) |

Note: General elective courses are non-professional courses designed to give the student a broad understanding in traditional and contemporary fields of thought outside of natural science and mathematics. The elective program (30 hours minimum) shall include at least twelve hours of humanities and twelve hours of social sciences.

**required preliminary courses** (65 credit hours)

| | |
|---|---|
| Math 21 | Analytic Geometry and Calculus I (4) |
| Math 22 | Analytic Geometry and Calculus II (4) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| Phys 11 | Introductory Physics I (4) |
| Phys 12 | Introductory Physics Laboratory I (1) |
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |
| Chem 21 | Introductory Chemical Principles (4) |
| Chem 22 | Chemical Principles Laboratory (1) |
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) |
| Chem 51 | Organic Chemistry (3) |
| Chem 53 | Organic Chemistry Laboratory (1) |
| Geol 11 | Environmental Geology (3) |
| Geol 21* **or** Geol 161 | Principles in Geology (3) **or** Geology for Engineers (3) |
| Geol 31* | Historical Geology (3) |
| Geol 133 | Introduction to Mineralogy (3) |
| Biol 21 | Principles of Biology (3) |
| Biol 22 | Introduction to Biology Laboratory (1) |
| Biol 133 | Invertebrate Zoology (3) |
| Biol 151 | Vertebrate Field Biology (3) |
| Biol 211 **or** Biol 309 | Ecology (3) **or** Aquatic Biology (3) |
| Eco 311 **or** Eco 314 | Environmental Economic (3) **or** Energy Economics (3) |
| Jour 123 | Basic Science and Technical Writing (3) |

*Geol 41 Physical and Historical Geology in the Rocky Mountains (6) may be substituted for Geol 21 and 31 (6).

### *Concentrations*

Eighteen credit hours required. Students should select and fulfill one of the following areas of concentration. The courses in each concentration area have been recommended and approved by the respective departments.

### *Geology Concentration*

| | |
|---|---|
| Geol 223 | Structural Geology (3) |
| Geol 112 | Geomorphology (3) |
| Geol 213 | Sedimentology & Stratigraphy (3) |
| Geol 135 **or** | Introduction to Lithology and Petrography (3) **or** |
| Geol 356 | Ground Water (3) |
| Geol 341 | Field Geology (6) |

### *Biology Concentration*

| | |
|---|---|
| Biol 28 | Mendelian and Population Genetics (3) |
| Biol 131 or | Non-Vascular Plants (3) or |
| Biol 132 | Evolution of Vascular Plants (3) |
| Biol 223 | Animal Physiology (3) |
| Biol 235 | Microbiology (3) |
| Chem 52 | Organic Chemistry (3) |
| Biol | Approved Field Course (3) |

### *Chemistry Concentration*

| | |
|---|---|
| Chem 52 | Organic Chemistry (3) |
| Chem 54 | Organic Chemistry Laboratory (2) |
| Chem 187 | Physical Chemistry I (3) |
| Chem 189 | Physical Chemistry II (3) |
| Chem 234 | Analytical Chemistry Laboratory (1) |
| Chem 332 | Analytical Chemistry (3) |
| CE 374 | Environmental Chemistry (3) |

### *Environmental Science Writing Concentration*

| | |
|---|---|
| Jour 12 or | Feature Writing (3) or |
| Jour 214 or | Reporting of Public Affairs (4) or |
| Jour 312 | Advanced Science Writing (3) |
| Jour 113 | Editing (3) |
| Jour 124 | Politics of Science (3) |
| Jour 125 | Environment, the Public and the Mass Media (3) |
| Jour 128 | Writing for Public Relations (3) |
| Jour 313 | Special Topics in Science Writing (3) |

### *Recommended Sequence of Courses*

**freshman year, first semester** (15 credit hours)

| | |
|---|---|
| Math 21 | Analytic Geometry and Calculus I (4) |
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |
| Engl 1 | Composition and Literature (3) |
| | general elective (3) |

**freshman year, second semester** (13 credit hours)

| | |
|---|---|
| Math 22 | Analytic Geometry and Calculus II (4) |
| Geol 21* | Principles of Geology (3) |
| Engl 2, 4, 6, 8 or 10 | Composition and Literature: Fiction, Drama, Poetry (3) |
| | general elective (3) |

**summer**

| | |
|---|---|
| Geol 41* | Physical and Historical Geology in the Rocky Mountains (6) |

(this course may be substituted for Geol 21 and 31)

**sophomore year, first semester** (16 credit hours)

| | |
|---|---|
| Math 23 | Analytic Geometry and Calculus III (4) |
| Phys 11, 12 | Introductory Physics I and Laboratory I (5) |
| Biol 21, 22 | Principles of Biology and Laboratory (4) |
| Geol 11 | Environmental Geology (3) |

**sophomore year, second semester** (14 credit hours)

| | |
|---|---|
| Phys 21, 22 | Introductory Physics II and Laboratory II (5) |
| Geol-31* | Historical Geology (3) |
| | concentration course (3) |
| | general elective (3) |

**junior year, first semester** (16 credit hours)

| | |
|---|---|
| Chem 51, 53 | Organic Chemistry and Laboratory (4) |
| Geol 133 | Introduction to Mineralogy (3) |
| Biol 151 | Vertebrate Field Biology (3) |
| | concentration course (3) |
| | general elective (3) |

**junior year, second semester** (15 credit hours)

| | |
|---|---|
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) |
| Biol 211 or | Ecology (3) or |
| Biol 309 | Aquatic Biology (3) |
| | concentration course (3) |
| | general electives (6) |

**summer**

| | |
|---|---|
| Geol 341 | Field Geology (6) |
| | Geology concentration only. |
| Biol | Approved field course (3) |
| | Biology concentration only. |

**senior year, first semester** (15 credit hours)

| | |
|---|---|
| Biol 133 | Invertebrate Zoology (3) |
| Jour 123 | Basic Science and Technical Writing (3) |
| | concentration course (3) |
| | general electives (6) |

**senior year, second semester** (15 credit hours)

| | |
|---|---|
| Eco 311 or | Environmental Economics (3) or |
| Eco 314 | Energy Economics (3) |
| | concentration courses (6) |
| | general electives (6) |

# Finance

**Professors.** Carl R. Beidleman, Ph.D. (Pennsylvania), *DuBois Professor of Finance, chairperson;* Eli Schwartz, Ph.D. (Brown), *Macfarlane Professor of Economics.*
**Associate professors.** Stephen G. Buell, Ph.D. (Lehigh); James A. Greenleaf, Ph.D. (N.Y.U.), Stephen F. Thode, D.B.A. (Indiana).
**Assistant professors.** Richard J. Kish, Ph.D. (Univ. of Florida); John David Leahigh, Ph.D. (Georgetown); Geraldo M. Vasconcellos, Ph.D. (Univ. of Illinois).
**Instructor.** Phillip M. Sisneros, B.B.A. (New Mexico).

The finance major offered in the College of Business and Economics requires fifteen credit hours beyond the core listed on page 00. Each finance major selects either the Business Finance or Financial Economics track.

#### *Business Finance*

required courses:

| | |
|---|---|
| Fin 323 | Investments (3) |
| Fin 328 | Corporate Financial Policy (3) |

plus two of the following:

| | |
|---|---|
| Fin 324 | Security Analysis (3) |
| Fin 330 | Financial Flows and Markets (3) |
| Fin 331 | Bank Management (3) |
| Fin 333 | Multinational Business Finance (3) |
| Fin 334 | Speculative Markets (3) |
| Fin 335 | Advanced Financial Modeling (3) |

plus one additional 300-level finance or finance/economics course.

#### *Financial Economics*

required courses:

| | |
|---|---|
| Fin 323 | Investments (3) |
| Fin 328 | Corporate Financial Policy (3) |

plus two of the following:

| | |
|---|---|
| Fin 332 | Monetary-Fiscal Policy (3) |
| Fin 340 | International Finance (3) |
| Fin 353 | Public Finance: Federal (3) |
| Fin 354 | Public Finance: State and Local (3) |

plus one additional 300-level finance or finance/economics course.

## For Advanced Undergraduates and Graduates

**225. Business Finance (3)** fall-spring
Introductory corporation finance, which stresses a managerial

approach to asset management and capital structure. Financial policies regarding the acquisition of funds and their allocation among competing assets within the firm. Prerequisites: Eco 145, Eco 105, Math 41 and 44, Acct 51.

**323. Investments (3)** fall, spring
The nature of risk and the form of returns to financial assets. Investor objectives, attitudes, and constraints are considered within the risk-return matrix as the basis for investment decisions. Problems of timing, market characteristics, and portfolio management. Prerequisite: Fin 225. Greenleaf, Kish

**324. Security Analysis (3)** fall
Factors influencing the value of financial securities: earnings forecasts and expectations, uncertainty, required returns, supply and demand for securities and funds, and investor attitudes. Implications of market factors, technical approaches, timing, and screening. Prerequisites: Acct 111 and Fin 323. Not ordinarily open to CBE graduate students. Beidleman, Buell, Sisneros

**328. Corporate Financial Policy (3)** fall, spring
Advanced corporate finance; capital budgeting, working capital management, leasing, mergers, and financing. Case studies and complex problems. Prerequisite: Fin 225. Not ordinarily open to CBE graduate students. Thode, Sisneros

**330. Financial Flows and Markets (3)** fall
Functions and portfolios of financial intermediaries. Sectoral demand and supply of funds, nature and role of interest rates, term structure and forecasting, impact of inflation and regulation on financial intermediaries and markets, and current developments in the financial system. Prerequisites: Eco 229 and Fin 225. Not ordinarily open to CBE graduate students. Leahigh, Vasconcellos

**331. Bank Management (3)** spring
Management of bank assets and liabilities within U.S. system's legal and economic constraints. Bank Management Simulator is used to examine relationships between asset, liability, and profitability decisions. Prerequisites: Eco 229 and Fin 225 senior standing or consent of instructor. Not ordinarily open to CBE graduate students. Leahigh, Vasconcellos

**332. (Eco 332) Monetary-Fiscal Policy (3)**
Monetary, credit and fiscal policies of government and central banks, with particular reference to the policies of the United States Treasury and the Federal Reserve System. Prerequisite: Eco 119 or 229. Schwartz

**333. Multinational Business Finance (3)** spring
Issues that underlie the investment, financing, and dividend decisions of multinational firms, Current transactions in foreign currencies, direct and portfolio investment and associated risk management when dealing in foreign countries. Prerequisite: Fin 328. Not ordinarily open to cbe graduate students. Beidleman, Vasconcellos

**334. Speculative Markets (3)** spring
Theoretical and empirical analysis of speculation in various markets, particularly options and futures markets. Term project required. Not ordinarily open to CBE graduate students. Prerequisite: Fin 323. Greenleaf

**335. Advanced Financial Modeling (3)** fall
Modeling of complex financial decisions including bond refunding, security valuation, option pricing, currency swaps, and leasing. Utilizes the problem-solving capabilities of modern microcomputer spreadsheets. Prerequisites: Fin 323 and Fin 328 or consent of instructor. Not ordinarily open to CBE graduate students. Buell, Thode

**340. (Eco 340) International Finance (3)**
Analysis of balance of payments and disturbances and adjustment in the international economy; international monetary policies. Prerequisite: Eco 229. Callahan, Gunter

**353. (Eco 353) Public Finance: Federal (3)**
A course dealing with government expenditures and revenues, the economics of taxation, and government administration. Aronson, Munley

**354. (Eco 354) Public Finance: State and Local (3)**
The major issues regarding revenues, expenditures, debt and budgeting policy are examined in the light of fiscal principles and economic effects of state and local governments. Special attention is placed on intergovernmental fiscal relations. Aronson, Munley

**371. Directed Readings (3)**
Readings in various fields of finance designed for the student with a special interest in some field of finance not covered in scheduled courses. Prerequisite: consent of the department chairperson. May be repeated.

**372. Special Topics (1-3)**
Special problems and issues in finance for which no regularly scheduled course work exists. When offered as group study, coverage varies according to interests of instructor and students. Prerequisite: consent of department chairperson. May be repeated.

## For Graduate Students

**411. Financial Management (3)** fall
Introduction to financial management, with consideration of advanced topics, with respect to: risk, valuation, capital structure, dividends, capital budgeting, and working capital management. Prerequisites: Eco 408 (or concurrently) and Acct 403.

**430. Investments and Portfolio Management (3)** fall
Investment instruments and institutions, historical performance, technical analysis, risk and diversification, portfolio theory. Prerequisite: Fin 411. Greenleaf, Kish

**431. Advanced Investment and Portfolio Analysis (3)** spring
Theoretical and empirical examination of recent developments in portfolio theory. Prerequisite: Fin 430.

**432. Financial Management of Financial Institutions (3)** fall
Asset and liability management of commercial banks, savings and loan associations, life insurance companies, and pension funds. Short and long run responses to changes in economic conditions, interest rates, and regulations. Prerequisite: Fin 411. Leahigh, Vasconcellos

**433. (Eco 433) Valuation seminar (3)**
Determinants of financial asset values. The role of uncertainty, imprecise forecasts, risk preferences, inflation, and market conditions. Prerequisite: Fin 411. Beidleman, Buell, Sisneros

**434. Cases in Financial Management (3)**
Integration of multiple topics in corporation finance through analysis of complex cases, including: capital budgeting, working capital management, leasing, mergers, and financing. Prerequisite: Fin 411. Thode

**436. International Financial Management (3)**
Financial management of multinational firms. Consideration of problems arising from diversity of currencies, investment opportunities, risk, and international capital markets. Case studies. Prerequisite: Fin 411. Beidleman, Vasconcellos

**442. (Eco 442) Foreign Trade Management (3)** spring, odd-numbered years
Foreign operations, including export channels in foreign markets, export and import financing, foreign investments, and policies of government and international agencies.

**444. (Eco 444) Banking and Monetary Policy (3)**
Analysis of the U.S. monetary and banking systems. Financial markets. Central bank controls, monetary theory and policy. Prerequisite: a course in money and banking. Innes, Schwartz

**447. (Eco 447) Capital and Interest Theory (3)** alternate years
Theories of interest and capital. Annuities; applications of present value theory; investment valuation under uncertainty and risk; term

structure of interest rates; the theory of savings, cost of capital and capital formation. Prerequisite: a course in finance. Schwartz

**449. (Eco 449) Public Finance (3)** spring, even-numbered years
The economics of public spending and taxation; principles of government debt management; theories of budgeting and cost-benefit analysis and public choice. Aronson, Munley

**451. Quantitative Financial Models (3)** alternate years
Relationship of quantitative models to financial theory and applications. Capital budgeting, portfolio selection, security evaluation, cash management, inventory policy and credit analysis. Prerequisite: Fin 411. McNamara

**456. Options and Financial Futures (3)** spring
Examination of the options pricing model and its implications for options management and equity pricing. Theory and applications for hedging and speculation. Emphasis is placed on trading of options on debt, equity, stock indices and futures. Financial futures and index futures are also examined for their contributions to individual portfolio management. Prerequisite: Finance 430. Greenleaf

**457. (Eco 457) Monetary Theory (3)**
The role of money in the economy from theoretical and empirical perspectives. The influence of money and prices, interest rates, output and employment. Prerequisite: Eco/Fin 444 or equivalent. Innes, Callahan

**459. (Eco 459) International Financial Economics (3)**
Analysis of the structure and functioning of the international monetary system, international capital markets, Eurocurrency markets, fixed and floating exchange rates, and the role of international monetary institutions in foreign exchange risk management. Callahan, Gunter

**471. Directed Readings (1-3)**
Readings in finance not covered in regularly scheduled coursework. Prerequisite: consent of the department chairperson. May be repeated.

**472. Special Topics (1-3)**
Problems and issues in finance for which no regularly scheduled graduate course work exists. When offered as group study, coverage varies according to interest in finance. Prerequisite: consent of the department chairperson. May be repeated.

# Fine Arts

See listings under Art and Architecture.

# Five-Year Programs

There are a number of ways in which students can obtain two degrees in five years of study. See listings under Arts-Engineering; Arts-Master of Business Administration; Civil Engineering and Geological Sciences; Electrical Engineering and Engineering Physics; and Engineering-Master of Business Administration.

# Foreign Culture And Civilization

See listings under Modern Foreign Languages.

# Foreign Literature

See listings under Classics and under Modern Foreign Languages.

# French

See listings under Modern Foreign Languages.

# Fundamental Sciences

George E. Kane, M.S. (Lehigh Univ.), *associate dean* of the College of Engineering and Applied Science, *director* of the fundamental sciences program.

The curriculum in fundamental sciences is designed to enable students to achieve a breadth of academic background in the fields of modern science and at the same time, through an option, to master the discipline of one of them, approximately to the level of a minimum bachelor's program. The options and electives provide sufficient flexibility to enable a student to prepare for employment in industry or government or for graduate study in a field.

Fundamental science students are required to concentrate in a major. Students can organize acceptable programs including the substantive course elements related to any one among several areas such as chemistry, physics and mathematics, biology, earth and space science, science of living systems, materials, computer science, and architecture, or meaningful combinations of any two.

The freshman year is identical with that of all students in the College of Engineering and Applied Science. The General Studies requirements of the college must also be satisfied. The discipline of a field will be provided by the inclusion of at least fifteen semester hours or from a combination that constitutes the core of one of the combination fields. Examples of these combination major include: biochemistry, geophysics, bioengineering, applied mathematics, biophysics, and computer science. Students pursuing double concentrations may, with the approval of their adviser, substitute for one of the science courses of the sophomore year a basic course in the area of concentration.

The details of the student's program are worked out by the student with the advice of the curriculum adviser, and with the approval of the department chairperson concerned with the fields of concentration.

## *Recommended Sequence of Courses*

**freshman engineering year** (see page 37)

**sophomore year, first semester** (15-16 credits)

| | |
|---|---|
| Biol 21, 22 | Principles of Biology and Laboratory (4) **or** |
| Geol 21 | Principles of Geology (3) |
| Chem 51, 53 | Organic Chemistry and Laboratory (4) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| Eco 1 | Economics (4) |

**sophomore year, second semester** (17 credits)

| | |
|---|---|
| | major subject (3) |
| | approved elective (3) |
| Math 205 | Linear Methods (3) |
| Phys 21, 22 | Introductory Physics II and Laboratory (5) |
| | general studies elective (3) |

**junior year, first semester** (15-16 credit hours)

| | |
|---|---|
| Geol 21 | Principles of Geology (3) **or** |

| | |
|---|---|
| Biol 21, 22 | Principles of Biology and Laboratory (4) |
| Psyc 1 | Introduction to Psychology (3) |
| Math 231 | Probability and Statistics (3) |
| | major (3) |
| | general studies elective (3) |

**junior year, second semester** (15 credit hours)

| | |
|---|---|
| | approved electives (6) |
| | major (6) |
| | elective (3) |

**senior year, first semester**(18 credit hours)

| | |
|---|---|
| | approved electives (6) |
| | major (6) |
| | general studies elective (3) |
| | elective (3)* |

**senior year, second semester** (18 credits)

| | |
|---|---|
| Phil 128 | Philosophy of Science (3) |
| | approved elective (3) |
| | major (6) |
| | general studies elective (3) |
| | elective (3)* |

# Geological Sciences

**Professors.** Bobb Carson, Ph.D. (Washington), *chairperson;* Edward B. Evenson, Ph.D. (Michigan); Paul B. Myers, Jr., Ph.D. (Lehigh); Charles B. Sclar, Ph.D. (Yale); Dale R.Simpson, Ph.D. (Cal. Tech.).
**Associate professor.** Kenneth P. Kodama, Ph.D. (Stanford).
**Assistant professors.** David J. Anastasio, Ph.D. (Johns Hopkins); Carl O. Moses, Ph.D. (Virginia); Peter K. Zeitler, Ph.D. (Dartmouth).

Geology, geophysics, and geochemistry deal with natural phenomena on or within the earth. Each makes use of other more fundamental sciences in its practice; hence, the student preparing for a career in one of the geological sciences combines study in geology with a broad understanding of physical, chemical, and biological principles.

Lehigh offers two undergraduate programs in geological sciences, one leading to the degree of bachelor of science in geological sciences, the other to the degree of bachelor of arts. The bachelor of science curriculum is designed to permit a concentration in depth in the major whereas the bachelor of arts curriculum provides the opportunity for a broad liberal-arts education centered around geoscience. The bachelor of arts program requires fewer credits for graduation (123 vs. 127 credit hours), fewer courses in collateral sciences and mathematics (28-32 vs. 33 credit hours), and fewer required geology courses (31 vs. 42 credit hours). Candidates for the bachelor of science degree also are required to take fifteen credit hours in approved professional electives. The professional electives permit the student to arrange for an informal option in geochemistry, geophysics, engineering geology, etc. If the free electives in the bachelor of arts program are selected carefully, the B.A. program would provide the possibility of (1) a minor in an area of the humanities and social sciences; and (2) entry into graduate-level studies in fields such as geology, environmental science, marine science, environmental law, etc. Students are strongly urged to discuss the selection of free electives, career goals, and career objectives with their major advisor.

Students electing the bachelor of arts program are required to meet the distribution requirement of the College of Arts and Science; candidates for the bachelor of science degree take thirty credit hours of nonprofessional electives in place of the distribution requirements.

Both the bachelor of science program and the bachelor of arts program provide preparation for graduate school. Qualified students may be given permission at the end of the junior year to enter a program wherein they are able to begin work toward a graduate degree during the senior year. (See Combined B.A. or B.S. and M.S. program below.)

Geological training may be utilized in industry (especially in the petroleum, mining, construction engineering, ceramics, and metallurgical industries), government service, natural resource management, and in secondary school, college, and university teaching.

A major in geophysics is offered in conjunction with faculty from cooperating departments. This program is described under "Geophysics."

## *Major Requirements for B.S.*

A total of 127 credit hours is required.

**college and university requirements** (37 credit hours)

| | |
|---|---|
| Engl 1 | Composition and Literature (3) |
| Engl 2, 4, 6, | Composition and Literature or |
| 8, or 10 | Composition and Film Study (3) |
| Arts and Science 1 | Choices and Decisions |
| | electives (30 credit hours) |

Elective courses are nonprofessional courses designed to give the student a broad understanding in traditional and contemporary fields of thought outside of natural science and mathematics. The courses are chosen by the student. The elective program includes a minimum of 12 credit hours in the humanities and a minimum of 12 credit hours in the social sciences as defined by the faculty for the bachelor of arts.

**major program** (90 credit hours)

*mathematics* (12 credit hours)

| | |
|---|---|
| Math 21 | Analytic Geometry and Calculus I (4) |
| Math 22 | Analytic Geometry and Calculus II (4) |
| Math 23 | Analytic Geometry and Calculus III (4) |

*collateral sciences* (21 credit hours)

| | |
|---|---|
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |
| Chem 187 | Physical Chemistry I (3) |
| Phys 11, 12 | Introductory Physics I and Laboratory (5) |
| Phys 21, 22 | Introductory Physics II and Laboratory (5) |
| CSc 11 | Introduction to Structured Programming (3) |

*geology* (42 credit hours)

| | |
|---|---|
| Geol 11 | Environmental Geology (3) **or** |
| Geol 21 | Principles of Geology (3) **or** |
| Geol 161 | Geology for Engineers (3) **and** |
| Geol 31 | Historical Geology (3) **or** |
| Geol 41 | Physical and Historical Geology in the Rocky Mountains (6) |
| Geol 112 | Geomorphology (3) |
| Geol 122 | Introduction to Plate Tectonics (3) |
| Geol 133 | Introduction to Mineralogy (3) |
| Geol 134 | Introduction to Optical Mineralogy and Crystallography (3) |
| Geol 135 | Introduction to Lithology and Petrography (3) |
| Geol 171 | Introduction to Aqueous Geochemistry (3) |
| Geol 212 | Paleontology (3) |
| Geol 213 | Sedimentology and Stratigraphy (3) |
| Geol 223 | Structural Geology (3) |
| Geol 301 | Introduction to Geophysics (3) |
| Geol 341 | Field Geology (6) |

Note: Geol 41 may be substituted for Geol 21, and 31. Before taking Geol 341, it is recommended that a student complete Geol 21, 31, 112, 133, 213, and 223.

*approved professional electives* (15 credit hours)
Courses approved to fulfill this requirement should form a coherent package supporting the professional objectives of the student. At least one professional elective, approved by the director of undergraduate studies, must be a science, math, or engineering course, taken outside of the Department of Geological Sciences. Examples of coherent groups of courses that may serve to fulfill this requirement are as follows:

**Emphasis on Mineralogy-Petrology-Economic Geology**

| | |
|---|---|
| Geol 334 | Igneous and Metamorphic Petrology (3) |
| Geol 336 | Mineral Phase Relations (3) |
| Geol 337 | X-ray Diffraction of Materials (3) |
| Geol 338 | Electron Microscopy and Microanalysis (4) |
| Geol 357 | Economic Geology (3) |
| Geol 372 | Solid Earth Geochemistry (3) |
| Geol 374 | Isotope Geochemistry and Geochronology (3) |

**Emphasis on Surficial and Sedimentary Geology**

| | |
|---|---|
| Geol 314 | Glacial and Quaternary Geology (3) |
| Geol 315 | Soil Genesis (3) |
| Geol 318 | Genesis of Carbonate Rocks (3) |
| Geol 326 | Evolution of North America (3) |
| Geol 335 | Sedimentary Petrology (3) |
| Geol 361 | Statistical Applications (3) |
| Geol 371 | Water Quality Principles and Measurements (3) |
| Geol 375 | Water-Rock Interaction Seminar (3) |
| CE 143 | Soil Mechanics (4) |

**Emphasis on Tectonics**

| | |
|---|---|
| Geol 302 | Solid Earth Geophysics (3) |
| Geol 306 | Geophysical Field Techniques (3) |
| Geol 324 | Structural Analysis (3) |
| Geol 326 | Evolution of North America (3) |
| Geol 334 | Igneous and Metamorphic Petrology (3) |
| Math 205 | Linear Methods (3) |

**Emphasis on Hydrogeology**

| | |
|---|---|
| Geol 306 | Geophysical Field Techniques (3) |
| Geol 315 | Soil Genesis (3) |
| Geol 316 | Hydrogeology (3) |
| Geol 335 | Sedimentary Petrology (3) |
| Geol 361 | Statistical Applications (3) |
| Geol 371 | Water Quality Principles and Measurements (3) |
| Geol 375 | Water-Rock Interaction Seminar (3) |
| CE 381 | Special Topics (1-3) |

Other coherent groups of courses that meet the specific objectives of the individual student may be selected with the approval of the faculty advisor.

## *Recommended Sequence of Science Courses*

**freshman year**

| | |
|---|---|
| Geol 21 | Principles of Geology (3) **and** |
| Geol 31 | Historical Geology (3) **or** |
| Geol 41 | Physical and Historical Geology in the Rocky Mountains (6) (summer preceding or following freshman year) |
| Math 21, 22 | Analytic Geometry and Calculus I and II (8) |
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |
| Phys 11, 12 | Introductory Physics I and Laboratory (5) |

**sophomore year**

| | |
|---|---|
| Geol 112 | Geomorphology (3) |
| Geol 122 | Introduction to Plate Tectonics (3) |
| Geol 133 | Introduction to Mineralogy (3) |
| Geol 134 | Introduction to Optical Mineralogy and Crystallography (3) |
| Geol 171 | Introduction to Aqueous Geochemistry (3) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| Phys 21, 22 | Introductory Physics II and Laboratory (5) |
| CSc 11 | Introduction to Structured Programming (3) |

**junior year**

| | |
|---|---|
| Geol 135 | Introduction to Lithology and Petrography (3) |
| Geol 212 | Paleontology (3) |
| Geol 213 | Sedimentology and Stratigraphy (3) |
| Geol 223 | Structural Geology (3) |
| Chem 187 | Physical Chemistry I (3) |
| | two professional electives (6) |

**summer following junior year**

| | |
|---|---|
| Geol 341 | Field Geology (6) |

**senior year**

| | |
|---|---|
| Geol 301 | Introduction to Geophysics (3) |
| | three professional electives (9) |

## *B.A. in Geological Sciences*

A total of 123 credit hours is required.

**college and university requirements** (45 credit hours)

| | |
|---|---|
| Engl 1 | Composition and Literature (3) |
| Engl 2, 4, 6, 8, or 10 | Composition and Literature or Composition and Film Study (3) |
| Arts and Science 1 | Choices and Decisions |

distribution requirements:
- Preliminary Humanities and Social Science (12)
- Upper Class Requirements in Humanities and Social Science (20)
- Foreign language or cultures (6)

*collateral sciences* (19-21 credit hours)

| | |
|---|---|
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |
| Biol 21, 22 | Principles of Biology and Laboratory (4) **or** |
| Biol 133 | Invertebrate Zoology (3) |
| Phys 11, 12 | Introductory Physics I and Laboratory (5) |

one follow-up course in any of the above fields (3)

| | |
|---|---|
| CSc 11 | Introduction to Structured Programming (3) **or** |
| CSc 17 | Structured Programming and Data Structures (4) |

*mathematics* (9-12 credits)

| | |
|---|---|
| Math 21, 22, 23 | Analytic Geometry and Calculus I, II and III (12) **or** |
| Math 41, 43, 44 | BMSS Calculus I, Linear Algebra and Calculus II (9) |

*geology* (31 credit hours)

| | |
|---|---|
| Geol 21 | Principles of Geology (3) **and** |
| Geol 31 | Historical Geology (3) **or** |
| Geol 41 | Physical and Historical Geology in the Rocky Mountains (6) |
| Geol 133 | Introduction to Mineralogy (3) |
| Geol 223 | Structural Geology (3) |
| Geol 341 | Field Geology (6) |
| | Geology electives (12) |

*free electives* (13-17 credits)

## *Recommended Sequence of Science Courses for the B.A. Degree*

**freshman year**

| | |
|---|---|
| Geol 21 | Principles of Geology (3) **and** |
| Geol 31 | Historical Geology (3) **or** |
| Geol 41 | Physical and Historical Geology in the Rocky Mountains (6) (summer preceding or following freshman year) |
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |

| | |
|---|---|
| Phys 11, 12 | Introductory Physics I and Laboratory (5) |
| Math 21, 22 | Analytic Geometry and Calculus i and II (8) **or** |
| Math 41, 43 | BMSS Calculus I and Linear Algebra (6) |

**sophomore year**

| | |
|---|---|
| Geol 133 | Introduction to Mineralogy (3) |
| CSc 11 | Introduction to Structured Programming (3) **or** |
| CSc 17 | Structured Programming and Data Structures (4) |
| Biol 21, 22 | Principles of Biology and Laboratory (4) **or** |
| Biol 133 | Invertebrate Zoology (3) |
| Math 23 | Analytic Geometry and Calculus III (4) **or** |
| Math 44 | BMSS Calculus II (3) |

one follow-up course in physics, chemistry, or biology

**junior year**

| | |
|---|---|
| Geol 223 | Structural Geology (3) |
| | geology electives(6) |

**summer following junior year**

| | |
|---|---|
| Geol 341 | Field Geology (6) |

**senior year**

| | |
|---|---|
| | geology electives(6) |

## *Geology Minor*

A minor in geological sciences may be achieved by completing the following requirements:

| | |
|---|---|
| Geol 21 | Principles of Geology (3) **and** |
| Geol 31 | Historical Geology (3) **or** |
| Geol 41 | Physical and Historical Geology in the Rocky Mountains (6) |
| Geol 133 | Introduction to Mineralogy (3) |
| Geol 223 | Structural Geology (3) |
| | geology elective on 300-level (3) |

## *Combined B.A. or B.S. and M.S. Program in Geological Sciences*

The department of geological sciences offers a combined bachelor of arts or bachelor of science and master of science program. Students working toward the bachelor of arts or the bachelor of science in geological sciences who are enrolled in this program are permitted to take courses that apply toward the master of science degree during their senior year. During the student's senior year, the normal undergraduate tuition will cover the costs of all courses taken, including those that are taken for graduate credit.

After receiving the bachelor's degree, students registered in the program may acquire, if eligible for admission to The Graduate School, full-time graduate status, and, as such, they may apply for appointment to a teaching or research assistantship or graduate fellowship.

The program is designed for those students who, upon completing the junior year and the field camp requirement, need less than thirty credit hours to complete work for the bachelor's degree. To be accepted into the program, students should have a superior record of academic performance.

Application for admission to the program should be made no later than the beginning of the first semester of the senior year and must be approved by the department faculty and the dean of Graduate Studies. The application must include: a tentative master of science program approved by the department's director of graduate studies, and a roster, also approved by the department's director of graduate studies, showing which courses taken during the senior year apply toward the bachelor's degree and which courses apply toward the master's degree. No more than fifteen credit hours per semester may be rostered. All of the normal requirements for each degree as outlined must be fulfilled.

Students enrolled in this program should make application for admission to full-time graduate status after completing the first semester of the senior year.

## *Program in Civil Engineering and Geological Sciences*

The Department of Geological Sciences, in conjunction with the Department of Civil Engineering, administers a five-year program in geological engineering that leads to a bachelor of science degree in civil engineering and a bachelor of science degree in geological sciences. This is described under Civil Engineering and Geological Sciences, page 110.

## Undergraduate Courses

**5. Introduction to Gemology (3)** spring
Physical and chemical properties of natural and synthetic gems and crystals of technical importance. Their mode of occurrence as minerals, crystal structure, synthesis methods and non-destructive methods of identification and characterization. Laboratory work will include the determination of diagnostic optical properties, identification by x-ray diffraction methods, and an introduction to analytical scanning electron microscopy. Sclar

**11. Environmental Geology (3)** fall-spring
Analysis of the dynamic interaction of geologic processes and human activities. Catastrophic geologic processes, resource limitations and development, pollution of geologic systems, environmental legislation, engineering case studies. Evenson

**21. Principles of Geology (3)** fall-spring
Fundamental concepts of geology; the composition, structure, and development of the earth; processes of geological change. Lectures, laboratory, and field trip.

**31. Historical Geology (3)** spring
Origin and evolution of the earth and its lithosphere, hydrosphere, biosphere, and atmosphere. The dynamics of global-scale systems and evolution of climate. Fundamental principles of startigraphy, development of the geological timescale, and methods of dating and correlation. Paleogeographic and paleoenvironmental reconstruction. Lectures, laboratories and discussion sessions. Prerequisite: Geol 11, 21 or 161. Zeitler

**41. Physical and Historical Geology in the Rocky Mountains (6)** summer
Six-week field course taught in Wyoming and Idaho. Morning and evening lectures combined with afternoon field exercises. See Geol 21 and 31 for course content. See Geol 341 for location details. Prerequisite: consent of chairman. Evenson and Myers

**112. Geomorphology (3)** spring
Sytematic study of the origin, evolution, and distribution of the earth's topographic features, land forms analyzed in terms of chemical and physical processes responsible for their development. Lectures and required field trips. Prerequisite: Geol 21 or 161. Evenson

**122. Introduction to Plate Tectonics (3)** fall
Theory of plate tectonics with emphasis on plate geometry, geophysical relationships and geological consequences. Lectures and laboratory. Prerequisites: Geol 11 or 21 or 161. Kodama and Zeitler

**133. Introduction to Mineralogy (3)** fall
Principles of crystallography and mineralogy; megascopic study, identification, and description of common minerals. Lectures and laboratory. Simpson

**134. Introduction to Optical Mineralogy and Crystallography (3)** spring
Fundamentals of crystallography and crystal structure; patterns and symmetries, symmetry notations; optical mineralogy and mineral identification. Lectures and laboratory. Prerequisite: Geol 133. Simpson

**135. Introduction to Lithology and Petrography** (3) fall
Description and classification of rocks in hand specimens and thin sections. Lectures and laboratories. Prerequisites: Geol 133 and 134. Sclar

**161. Geology for Engineers** (3) fall
A study of the materials that make up the earth, the physical, chemical, and environmental history that they relate, and the processes that act to change them. Designed primarily for upperclass science and engineering majors. Lectures and laboratory. Myers

**171. Introduction to Aqueous Geochemistry** (3) spring
Introduction to chemical thermodynamics, physicochemical properties of water, acid-base chemistry, aqueous speciation, and mineral solubility. Emphasis on the global water cycle and biogeochemical cycles of the elements. Lectures and laboratory. Prerequisites: Chem 21 and Geol 133. Moses

**212. Paleontology** (3) spring
Morphology of invertebrate fossils, their use in interpreting geologic history; evolution of the faunas and floras. Lectures and laboratory work.

**213. Sedimentology and Stratigraphy** (3) fall
Processes of sediment transport, deposition, and diagenesis of clastic and non-clastic sediments; sedimentary textures and structures; lithostratigraphy and stratigraphic correlation using biologic, magnetic, seismic, and radiometric methods. Lectures and laboratories. Prerequisites: Geol 135, previously or concurrently, and Geol 112. Carson

**223. Structural Geology** (3) fall
Application of basic concepts of stress, strain, and material properties to the study of folds, faults, fabrics, and other deformational structures in the earth's crust. Introduction to geometrical and field techniques. Lectures, laboratories and field trips. ~~Prerequisite: Geol 21 or 161~~. Anastasio

**281. Geological Research (1-3)** fall
Independent investigation of a special problem in the field, laboratory, or library. Prerequisite: consent of chairperson.

**282. Geological Research (1-3)** spring
Independent investigation of a special problem in the field, laboratory, or library. Prerequisite: consent of chairperson.

## For Advanced Undergraduates and Graduate Students

**301. Introduction to Geophysics** (3) fall
Gravitational, magnetic, seismic, electrical, and thermal properties of the earth. Interpretation of field measurements to resolve crustal and near-surface earth structure. Lectures and laboratories. Prerequisites: Math 21, Phys 21, Geol 223, or consent of instructor. Kodama

**302. Solid Earth Geophysics** (3) spring (alternate years)
Study of rotation and figure of the earth, global seismology and internal structure of the earth, heat flow and convection, geomagnetism, geodynamics, and planetology. Prerequisites: Math 21, Phys 21. Kodama

**306. Geophysical Field Techniques** (3) spring (alternate years)
Geophysical field investigation in an area of geological interest. Theory and application of seismic, gravity, magnetism, and electrical methods; data collection, interpretation, and written reports. Prerequisite: Geol 301 or consent of department chairperson. Kodama

**315. Soil Genesis** (3) fall (alternate years)
A geologic approach to the genesis, classification and application of pedology. Weathering of parent materials; chemistry of soils; geologic, biologic, and climate controls on soil formation; geologic and engineering geologic applications of soils. Field and laboratory investigations will acquaint the student with modern analytic techniques. Two lectures and one laboratory/discussion per week. Prerequisite: Geol 213 or consent of the department chairperson. Evenson, Myers, Moses

**316. Hydrogeology** (3) fall
Interrelationships of geologic materials and processes with water; entry, storage, interaction, and flow of water through permeable earth materials; evaluation, development, and management of ground-water resources. Prerequisites: Chem 21, 22, Geol 11, 21, or 161. Myers

**317. (Biol 317) Evolution** (3)
The origin of species and higher categories with emphasis on animals. Isolating mechanisms, population structure, rates of evolution, extinction. Prerequisite: two semesters of biology or consent of department chairperson.

**318. Genesis of Carbonate Rocks** (3) spring (alternate years)
Seminars, local field trips, and ten-day (Spring Vacation) field trip to the Florida Keys. Geology and biology of modern and ancient carbonate environments; biology and ecology of major carbonate-producing organisms. Origin, deposition, lithification, diagenesis, and classification of carbonate rocks. Evenson and Anastasio

**324. Structural Analysis** (3) fall (alternate years)
Field methods emphasizing interpretation of minor structures and practical application of geologic strain and petrofabric analysis applied to regional geologic problems. Seminars, laboratories, and field trips. Prerequisite: Geol 223. Anastasio

**326. Evolution of North America** (3) spring
A senior seminar on the lithologic, tectonic, and morphologic evolution of North America; developed within the framework of the plate tectonic theory. Staff

**334. Igneous and Metamorphic Petrology** (3) spring (alternate years)
Petrogenesis of igneous and metamorphic rocks and their distribution in space and time as related to past and present plate tectonic events. Microscopic study of rock suites. Lectures and laboratory. Prerequisite: Geol 134.

**335. Sedimentary Petrology** (3) spring (alternate years)
Origin, composition, and classification of sedimentary rocks; facies analysis and characteristics of continental, continental margin, and marine environments; facies as indicators of source, depositional environment, and tectonic setting. Lectures and laboratories. Prerequisites: Geol 135, 213. Carson

**336. Mineral Phase Relations** (3) spring (alternate years)
Principles of phase equilibria; unicomponent and multicomponent condensed systems and multicomponent systems with volatile phases. The application of phase relation studies to mineralogical and geological problems. Prerequisites: Geol 133, 134. Lectures and laboratory. Simpson

**337. (Chem 337, Mat 333) X-ray Diffraction of Materials** (3) fall
Emphasis on materials characterization with computer-controlled powder diffractometers. Specific topics include x-ray spectroscopy, crystallographic notation, orientation of single crystals, preferred orientations in polycrystals, crystallite size measurement, phase identification, quantitative analysis of crystalline phases, and stress measurement. Applications in mineralogy, metallurgy, ceramics, microelectronics, polymers, and catalysts. Lectures and laboratory work. Prerequisite: consent of department chairperson. Lyman

**338. (Mat 334) Electron Microscopy and Microanalysis** (4) fall
Fundamentals and experimental methods in electron optical techniques including scanning electron microscopy (SEM) conventional transmission (TEM) and scanning transmission (STEM) electron microscopy. Specific topics covered will include electron optics, electron beam interactions with solids, electron diffraction and chemical microanalysis. Applications to the study of the structure of materials are given. Prerequisite: consent of the department chairperson. Williams, Lyman

**339. Applied Mineralogy (3)** (alternate years)
Methods and approaches to the solution of industrial and environmental problems employing modern mineralogical techniques, especially transmitted-and incident-light polarizing microscopy and X-ray powder diffraction. Case histories of interest to geologists, chemists, ceramists, chemical, metallurgical, and mineral engineers, environmental engineers, and materials scientists. Lectures and laboratory. Prerequisite: Geol 134 or consent of the department chairperson. Simpson

**341. Field Geology (6)** summer
Field study and geologic mapping of sedimentary, igneous, metamorphic, and glacial deposits in the Rocky Mountains of northwestern Wyoming, and southeastern Idaho. Additional short studies in the Badlands and Black Hills of South Dakota, the Grand Tetons, Yellowstone Park, Craters of the Moon Park, and other areas in the Rocky Mountain region. Six weeks in the field. Summer session. Prerequisite: consent of the department chairperson. Graduate credit not given for this course. Evenson, Myers

**357. Economic Geology (3)** spring (alternate years)
The formation of mineral deposits and the occurrence and characteristics of deposits of economic importance. Includes metals, nonmetals and fuels. Lectures, laboratory work and inspection trips. Prerequisite: Geol 21. Simpson

**361. Statistical Applications (3)** fall (alternate years)
Statistical models applicable to geological, geochemical, and geophysical field and laboratory studies. Analysis of variance, applications of the chi-square distribution, analysis of covariance, linear, nonlinear and multiple regression, and distribution-free methods. Carson

**363. Case Histories in Engineering Geology (3)** spring
Methods of geological investigation at engineering sites. Assessing suitability of a proposed site, acquiring geological information for proper engineering design, and recognizing potential geotechnical problems during and after construction. Prerequisite: Geol 21 or 161. Myers

**371. Water Quality Principles and Measurements (3)** fall (alternate years)
Analytical and computational methods for generating and evaluating water quality data for surface and ground waters. Lectures and laboratories. Laboratories demonstrate sampling, field measurements of parameters, standard methods of chemical analysis, and computer applications. Prerequisites: CS 11, Geol 171, or equivalents. Moses

**372. Solid Earth Geochemistry (3)** spring (alternate years)
Synthesis of the geological, chemical, physical, and astronomical observations regarding the geochemical evolution of the earth, its internal constitution, and the physico-chemical processes which modify the crust. Crystal-chemical controls on the abundance of the elements and pressure studies of geochemical significance. Shock metamorphism as a geochemical process on the surface of the earth, moon and planets. Sclar

**373. Geochemical Thermodynamics (3)** fall
Macroscopic chemical thermodynamics with applications to geochemical processes. Thermodynamic relationships, geochemical equilibria, and an introduction to kinetics. Prerequisite: Geol 171, or Chem 31 and Geol 133. Moses

**374. Isotope Geochemistry and Geochronology (3)** fall (alternate years)
The use of radiogenic isotopic systems to determine the age, temperature history, and chemical evolution of rocks. Principles and applications of stable-isotope geochemistry. Radioactive decay and isotope systematics. Diffusion and fractionation effects. Lectures, seminars, and laboratories. Prerequisites: Math 21, Chem 21, Geol 122, 135, or consent of instructor. Zeitler

**375. Water-rock Interaction Seminar (3)** fall-spring
Discussions of current and "classic" literature in water-rock interactions, selected and presented by participants. Brief writing exercises. Prerequisites: Geol 171 and consent of instructor. Moses

## For Graduate Students

The graduate program in geological sciences is directed principally toward the study of geologic processes. Candidates for the master's degree receive instruction in several aspects of the geological sciences. Graduate students working toward the doctorate specialize in one field of geoscience. All graduate students are expected to take courses in collateral fields of science appropriate to their research interests.

Research is an important part of the graduate program. In general, students are encouraged to choose research problems that for their solution require the use of integrated laboratory and field studies.

Candidates for the master of science degree are required to complete a thesis that must be presented in the form specified by The Graduate School. The research for and writing of the thesis will be done under the direction of the thesis director who must be a member of the department faculty. The thesis director and two other members will constitute the thesis committee for the master of science candidate.

Students who enter the graduate program with a bachelor of science or bachelor of arts degree in geology and who wish to qualify for admission to candidacy for the doctor of philosophy degree must take the departmental qualifying examination prior to the fourth semester. Candidates with compelling reasons may petition to take the qualifying examination at a later date.

University requirements for graduate degrees are listed in The Graduate School section. Departmental regulations are included in the department's graduate student handbook.

Special departmental research facilities of interest include: Philips APD-3600 automated X-ray powder diffractometer; Philips AXS automated X-ray fluorescence spectrometer, Debye-Scherrer X-ray powder cameras; complete petrographic and incident-light microscopy facilities; hydrothermal apparatus for experimental mineralogy; belt-type ultra-high-pressure apparatus for upper mantle studies; complete laboratory for noble-gas and fission-track geochronology, including a low-blank, double vacuum resistance furnace and a VG Isotopes model 3600 mass spectrometer; paleomagnetism laboratory with a Molspin spinner magnetometer, a 2-Axis CTF Cryogenic Rock Magnetometer, a Schonstedt tumbling AF demagnetizer, and a Schonstedt thermal demagnetizer; sedimentation laboratory equipped with Particle Data computer-based particle-size analyzer and rapid sediment analyzer; field geophysical equipment including Bison shallow refraction seismic unit and Bison shallow resistivity apparatus, master Wordon gravimeter, Geometrics portable proton precession magnetometer; Keck borehold logging equipment including caliper, natural gamma, electrical resistivity, and self-potential probes; downhole geochemical sampling equipment; Waters computer-assisted ion chromatograph; Sun graphics workstations which support CADD, mapping/contouring software, and ARC/INFO geographic information system; standard equipment for field mapping.

Lehigh houses a station of the Pennsylvania Seismic Network that is equipped with a short-period vertical seismometer. Three wells are also located on campus as an *in situ* groundwater laboratory. Students perform a variety of pump tests, geochemical sampling, and down-hole geophysical determinations at this facility.

The following major analytical facilities are available on campus to students and staff of the department: fully automated JEOL 733 electron microprobe, Philips 300 electron microscope completely equipped for transmission and diffraction, ETEC scanning electron microscope with nondispersive analysis capability, Philips EM400, XTEM/STEM analytical electron microscope equipped for quantitative X-ray microanalysis and electron energy-loss spectroscopy; and Perkin Elmer double-beam infrared spectrophotometer.

**405. Paleomagnetism (3)** spring
Characteristics and history of the earth's magnetic field, rock magnetism, field and laboratory techniques, statistical analysis of paleomagnetic data, tectonic and geochronologic applications of paleomagnetism. Prerequisite: Phys 21. Kodama

**407. Seismology (3)** fall
Basic seismological concepts: design and characteristics of seismometers; interpretation of seismograms; ray paths, body and surface waves, surface wave dispersion, earth structure, and free

oscillations of the earth. Prerequisites: Math 23 and Phys 21. Kodama

**414. Glacial and Quaternary Geology (3)** fall (alternate years)
Study of the origin, distribution, and movement of present and past glaciers. Special emphasis on glacial land forms and deposits, quaternary stratigraphy and dating techniques, periglacial phenomena, and Pleistocene environments. Lectures and required field trips. Prerequisite: Geol 21 or 101 or consent of department chairperson. Evenson

**415. Quaternary Dating and Paleoclimatology (3)** spring (alternate years)
Quaternary climates and review of methods used to reconstruct and date past climatic variation. Types of proxy data available, the methods used in their analysis and interpretation, assumptions and limitations of the dating methods. Staff

**416. Marine Geology (3)** spring (alternate years)
Tectonic and sedimentary processes in the ocean basins. Paleoclimatic, geochemical, and geophysical implications. Prerequisites: Geol 122, 213, or equivalents. Carson

**426. Tectonic Processes (3)** fall
Current models of tectonic processes in intraplate settings and at plate boundaries. Critical evaluations by the class of the geological, geochemical and geophysical data sets which gave rise to these models. Prerequisites: Geol 122 or equivalent; at least one of Geol 223, 326, 334, or 335, or equivalent, or consent of department chairperson. Staff

**427. Thrust Belts (3)** spring (alternate years)
Geometry and mechanics of thrust belts and structural tools necessary to study orogenesis. Topics include thrust and normal faults, folds, minor structures, basement-cover problems, the plutonic and metamorphic hinterland, and foreland basins. Structures are placed in regional context: Andes, Appalachians, Caledonides, Himalayas, North America Cordillera, Pyrenees, or Western Alps. Lectures and field trips, including one long one. Prerequisite: Geol 223 or equivalent. Anastasio

**428. Stress and Strain in Rocks (3)** spring (alternate years)
Theory of continuum mechanics and application to analytical methods of geological strain analysis; rock material properties and micro-mechanisms of rock deformation; tectonic fabric development; kinematic analysis. Lectures and laboratories. Prerequisite: Geol 223 or equivalent. Anastasio

**429. Principles and Applications of Thermochronometry (3)** spring (alternate (even) years)
Determination of the thermal history of crustal rocks using geochronological and other methods. Diffusion and kinetics; application of the closure-temperature concept of geochronological and petrological systems. Determination of metamorphic P-T-t paths, determination of temperature histories using such methods as vitrinite reflectance, and integration of such data with geochronological results. Applications to igneous, metamorphic, and seminentary realms. Lectures, seminars, laboratories. Prerequisite: Geol 374 or equivalent, or consent of instructor. Zeitler

**437. Advanced Igneous Petrology (3)** alternate years
Origin of the diversity of igneous rocks as revealed by field and laboratory studies. Lectures, laboratory and field trips. Sclar

**438. Advanced Metamorphic Petrology (3)** alternate years
Processes involved in the transformation of rock masses under high pressure and temperature. Problems of the deep crust and upper mantle. Lectures, laboratory and field trips. Sclar

**454. Genesis of Metalliferous Deposits (3)** alternate years
Petrological concepts regarding the origin of metalliferous ore deposits. Laboratory includes ore-mineral synthesis, ore microscopy, and electron microprobe analysis of ores. Field examination of ore deposits at operating mines. Sclar

**473. Aqueous Geochemistry (3)** spring (alternate years)
Advanced study of physical and inorganic aqueous geochemistry, including homogenous and heterogenous equilibria, kinetics, and surface processes in water-rock systems. Computational modeling of water-rock systems. Prerequisites: Geol 171 or equivalent, computer programming (C, Pascal, or Fortran), and consent of instructor. Moses

**481. Geological Investigation (1-6)** fall-spring
Research on a special problem; field, laboratory, or library study; report required. Credit above three hours granted only when a different problem is undertaken.

**482. Geological Investigation (1-6)** fall-spring
Similar to Geol 481. Credit above three hours granted only when a different problem is undertaken.

**483. Advanced Topics in Quaternary Studies (1-6)**
Intensive study of topics in Quaternary geology not covered in more general courses.

**484. Advanced Topics in Modern Processes (1-6)**
Intensive study of modern geologic processes not covered in more general courses.

**485. Advanced Topics in Tectonics (1-6)**
Intensive study of tectonic processes and products not covered in more general courses.

**486. Advanced Topics in Petrogenesis (1-6)**
Intensive study of rock genesis not covered in more general courses.

# Geophysics

Kenneth P. Kodama, associate professor of geophysics, *director*.

Geophysics is the branch of the earth sciences in which physical principles are used to understand the subsurface geology and history of the earth. Geophysical methods are important both in the search for energy and mineral resources and in the delineation of groundwater supplies and the sources of their pollution. On a global scale geophysics has allowed us to unravel the history of continental drift and better understand the plate tectonic model. The program is designed to provide the background needed for graduate work in geophysics or the preparation for employment in the petroleum industry or geophysical consulting firms.

**college and university requirements** (36 credits)

| | |
|---|---|
| Engl 1 | Composition and Literature (3) |
| Engl 2, 10, 14, 16 | Composition & Literature (3) |
| | electives (30 credit hours) |

Elective courses are nonprofessional courses designed to give the student a broad understanding in traditional and contemporary fields of thought outside of natural science and mathematics. The courses are chosen by the student. The elective program includes a large number of courses broadly distributed among the various areas of the humanities and the social sciences.

**major program** (90-95 credit hours)

*mathematics* (18 credit hours)

| | |
|---|---|
| Math 21 | Analytic Geometry and Calculus I (4) |
| Math 22 | Analytic Geometry and Calculus II (4) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| Math 205 | Linear Methods (3) |
| Math 322 | Methods of Applied Analysis I (3) |

*collateral sciences* (8 credit hours)

| | |
|---|---|
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |
| Mat 210 | Metallurgical Thermodynamics (3) **or** |
| Phys 340 | Thermal Physics (3) |

*physics* (22 credit hours)

| | |
|---|---|
| Phys 11 | Introductory Physics I (4) |
| Phys 12 | Introductory Physics Laboratory I (1) |
| Phys 21 | Introductory Physics II (4) |
| Phys 22 | Introductory Physics Laboratory II (1) |
| Phys 190 | Electronics (3) |
| Phys 212 | Electricity and Magnetism I (3) |
| Phys 213 | Electricity and Magnetism II (3) |
| Phys 215 | Classical Mechanics I (3) |

*geology* (30 credit hours)

| | |
|---|---|
| Geol 21 | Principles of Geology (3) * |
| Geol 31 | Historical Geology (3) |
| Geol 133 | Introduction to Mineralogy (3) |
| Geol 134 | Introduction to Optical Mineralogy and Crystallography (3) |
| Geol 213 | Sedimentology and Stratigraphy (3) |
| Geol 223 | Structural Geology (3) |
| Geol 301 | Introduction to Geophysics (3) |
| Geol 302 | Solid Earth Geophysics (3) |
| Geol 341 | Field Geology (6) |

*Geol 41 (6) may be substituted for 21 and 31.

*approved professional electives* (12-17 credit hours)
Any courses approved by the adviser may be used to satisfy this requirement. The following are especially recommended:

| | |
|---|---|
| Geol 122 | Introduction to Plate Tectonics (3) |
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) |
| Geol 306 | Geophysical Field Techniques (3) |
| Geol 361 | Statistical Applications (3) |
| Geol 334 | Igneous and Metamorphic Petrology (3) |
| Geol 336 | Mineral Phase Relations (3) |
| Geol 171 | Introduction to Aqueous Geochemistry (3) |
| Geol 316 | Hydrogeology (3) |
| Math 323 | Methods of Applied Analysis II (3) |
| Math 208 | Complex Variables (3) |
| Math 309 | Theory of Probability (3) |
| Math 320 | Ordinary Differential Equations (3) |
| Math 344 | Linear and Integer Programming (3) |
| ME 231 | Fluid Mechanics (3) |
| Mat 92 | Structure and Properties of Materials (3) |
| Phys 31 | Introduction to Quantum Mechanics (3) |
| Phys 216 | Classical Mechanics II (3) |
| Phys 340 | Thermal Physics (3) |
| Phys 352 | Modern Optics (3) |
| Phys 261 | Optics, Spectroscopy, and Quantum Physics Laboratory (2) |
| Phys 190 | Electronics (3) |
| Phys 363 | Physics of Solids (3) |
| Phys 365 | Physics of Fluids (3) |

# German

See listings under Modern Foreign Languages.

# Government

**Professors.** Frank T. Colon, Ph.D. (Pittsburgh), *chairperson;* Donald D. Barry, Ph.D. (Syracuse), *University Professor;* Laura Katz Olson, Ph.D. (Colorado); Howard R. Whitcomb, Ph.D. (S.U.N.Y. at Albany).
**Associate professors.** Richard K. Matthews, Ph.D. (Toronto); Edward P. Morgan, Ph.D. (Brandeis).
**Assistant professors.** Albert H. Wurth Jr., Ph.D. (North Carolina); Frank L. Davis, Ph.D. (North Carolina); Hannah Stewart-Gambino, Ph.D. (Duke).

The major in government is designed to promote understanding of political ideas, institutions and processes and to develop skills in analyzing and evaluating political problems.

A balanced program within the discipline, one that exposes the student to various areas of inquiry in American institutions and political processes as well as in the comparative and philosophical perspectives of political analysis, has been the way in which the goals of the major program generally have been achieved. While the major program outlined below will prove adequate for most student needs, it may be that because of some special factors such as late transfer or unusual interests and/or abilities the outlined program does not accommodate some students. In that case the students may, in consultation with their adviser, develop a major program that in their judgment will more adequately fulfill those needs.

The faculty adviser to the student majoring in the government department is designated by the department. The adviser consults with the student and approves the major program. The adviser attempts to help the student relate courses offered by the department to the student's educational goals. The adviser also may act as a resource for the students, and may suggest courses in other disciplines, language courses, and courses in research techniques that may be of benefit.

A variety of experiential opportunities are available to undergraduates majoring in government. The department, for example, offers annually a Government and Law Internship and a Community Politics Internship that include opportunities for internship placements in either local government, private agencies or law offices. Students are also encouraged to apply for off-campus, internship opportunities, e.g., American University's Washington Semester Program.

Completion of the government major is considered suitable training for the undergraduate who wishes to go on to law school, to become a social science teacher, or to work as a governmental official, party or civic leader, public affairs commentator, or staff member of a government research bureau. In addition, the business sector continues to provide opportunities in areas such as banking, insurance, and marketing for bachelor of arts graduates with training in the social sciences. Graduate study is advisable for students contemplating certain careers: college teaching, research, or public management, for example.

The four core courses are required. Individual exceptions may be made, for good reasons, by the major adviser with the approval of the department chairman.

## *Major Requirements*

| | |
|---|---|
| Govt 1 | American Political System (3) |
| Govt 3 | Comparative Politics (3) |
| Govt 21 | Introduction to Research Methods (3) |
| Govt 100 | Introduction to Political Thought (3) |

*electives*
Seven elective courses with at least two courses from each of the following two fields:

*American politics, public law and interdisciplinary*

| | |
|---|---|
| Govt 77 | Urban Politics (3) |
| Govt 111 | The Politics of Environment and Natural Resources (3) |
| Govt 115 | Technology As Politics (3) |
| Govt 174 | Political Parties and Elections (3) |
| Govt 179 | The Politics of Women (3) |
| Govt 302 | Comparative State Politics (3) |
| Govt 306 | Public Policy Process (3) |
| Govt 317 | The American Presidency (3) |
| Govt 327 | Socialization and the Political System (3) |
| Govt 330 | Politics of the 1960's (3) |
| Govt 331 | Government and Law Internship (3) |
| Govt 332 | Community Politics Internship (3) |
| Govt 333 | The Social Psychology of Politics (3) |
| Govt 351 | Constitutional Law (3) |
| Govt 352 | Civil Rights (3) |
| Govt 354 | Administrative Law (3) |

| | |
|---|---|
| Govt 355 | Public Personnel (3) |
| Govt 359 | U.S. Congress (3) |
| Govt 360 | Public Administration (3) |

*Political theory and comparative politics*

| | |
|---|---|
| Govt 101 | Ancient Political Heritage (3) |
| Govt 102 | Modern Political Heritage (3) |
| Govt 161 | The Soviet Political System (3) |
| Govt 171 | Democracy (3) |
| Govt 308 | Ideologies in World Affairs (3) |
| Govt 318 | Communist Political Systems (3) |
| Govt 320 | Peasants and Revolution (3) |
| Govt 322 | Politics of Developing Nations (3) |
| Govt 324 | Political Systems in Transition (3) |
| Govt 325 | International Political Economy (3) |
| Govt 364 | Issues in Contemporary Political Philosophy (3) |
| Govt 367 | American Political Thought (3) |
| Govt 368 | Political Economy (3) |

## *Government Minor*

The minor consists of three of the four core courses listed above (Govt 1, Govt 3, Govt 21 and Govt 100) plus any two other government courses.

## *Public Administration Minor*

The minor consists of Govt 1 and Govt 360 plus three other courses chosen in consultation with the adviser for a total of fifteen credit hours.

## Undergraduate Courses

**1. American Political System (3)** fall-spring
Constitutional principles; organization and operation of the national government; the party system, citizenship, and civil rights.

**3. Comparative Politics (3)** fall-spring
The political systems of foreign countries; approaches to the study of comparative politics.

**21. Introduction to Research Methods (3)** fall-spring
The research techniques of political science including research design, statistical and nonstatistical analysis, and computer applications. Prerequisite: consent of the department chairperson. Davis

**77. Urban Politics (3)**
The structure and processes of city government in the United States; city-state and federal-city relationships; the problems of metropolitan areas; political machines and community power structures; the urban politics of municipal reform; city planning and urban renewal. Colon

**100. Introduction to Political Thought (3)** fall-spring
Some of the most significant ancient and modern political theorists: Plato, Aristotle, Machiavelli, Hobbes, Marx, and others. Matthews

**101. Ancient Political Heritage (3)**
Important political thinkers from the pre-Socratics to early, modern political theorists like Machiavelli. Matthews

**102. Modern Political Heritage (3)** fall-spring
Begins where Govt. 101 ends: from early, modern theorists (e.g., Hobbes) up to contemporary thinkers (e.g., Marcuse, Habermas). Matthews

**111. The Politics of Environment and Natural Resources (3)**
A survey of the major environmental, resource, energy and population problems of modern society, focusing on the United States. The politics of man's relationship with nature, the political problems of ecological scarcity and public goods, and the response of the American political system to environmental issues. Wurth

**115. Technology as Politics (3)**
Relationship of technology and technological change with politics and public policy. Review of theories of political significance of technology, including technological determinism, technology assessment, technological progress and appropriate technology. Specific issues in technology with emphasis on U.S. Wurth

**161. The Soviet Political System (3)**
The roles of the Communist Party, the Council of Ministers, the Supreme Soviet and other governmental and social organizations in governing the USSR. Barry

**171. Democracy (3)**
Theory and practice of democratic government in selected countries.

**174. Political Parties and Elections (3)**
Organization, functions, and behavior of parties in the United States; voting behavior, campaigns, and elections. Colon

**179. The Politics of Women (3)**
Major social and political issues relating to the role of women in American society. Study of other countries will be included for comparative analysis. Olson

## For Advanced Undergraduates and Graduate Students

**302. Comparative State Politics (3)**
Analysis of major questions relating to the role of the states in the American federal systems and their relationship with the national government. Colon

**306. Public Policy Process (3)**
Power relations and their impacts on selected public policy issues, specifically taxation, housing, environment, poverty, energy, the military, and health. Olson

**308. (IR 308) Ideologies in World Affairs (3)**
Theories of ideology; nationalism and imperialism; conservatism/liberalism/socialism; Marxism/Leninism/Maoism; fascism and militarism; Third World ideologies; current ideological trends. Wylie

**313. Teaching Government (3)**
Contemporary issues in the teaching of social studies in public and private schools, including those government decisions that affect the educational environment. The course focuses attention on a specific issue such as urban problems, comparative political systems, ideologies and American political institutions and processes. Designed primarily for secondary school teachers.

**314. Workshop in Teaching Government (3)**
Individual research projects contemporary issues and discussion of proposals for curriculum revisions in the public and private schools. Outside speakers will be invited to attend workshop sessions. Must be taken concurrently with Govt 313 when courses are offered together.

**317. The American Presidency (3)**
Role of the executive in the American political process. Includes an analysis of the historical development, selection process, and scope of executive power. Olson

**318. (IR 318) Communist Political Systems (3)**
Examination of Communist political systems outside the USSR and the operations of nonruling Communist parties.

**320. Peasants and Revolution (3)**
Comparative study of peasant participation in everyday strategies of survival and resistance and extraordinary events of rebellion and revolution. Case studies: traditional, contemporary, and socialist agrarian states. Countries may vary by semester.

**322. (IR 322) Politics of Developing Nations** (3)
Theories of political development in non-Western areas; modernization and nation building. Field studies and methods; contributions of related disciplines such as sociology and psychology.

**324. Political Systems in Transition** (3) spring
The responses of selected non-Communist states to contemporary problems. Topics vary semester by semester. May be repeated for credit with consent of department chairperson.

**325. (IR 325) International Political Economy** (3)
Development of forms of political management of the world economy since World War II, with emphasis on control of interdependence among the industrialized countries, achievement of equity in relations between developed and developing countries, and reintegration of the centrally planned economies into the international economy.

**327. Socialization and the Political System** (3)
The social ideological and economic foundations of American politics. Emphasis on supporting institutions-family, schools, and workplace-and processes that foster political attitudes and behavioral patterns. Morgan

**330. Politics of the 1960's** (3)
Social and political movements of the 1960's from the perspective of the American political tradition. Civil rights, black power, campus protests, Vietnam War policy-making, the anti-war movement, the counter-culture. Morgan

**331. Government and Law Internship** (3)
Integrated fieldwork and academic study. Internship with law offices, government agencies, or elected officials. May be repeated for credit. Prerequisite: consent of the department chairperson.

**332. Community Politics Internship** (3)
Integrated fieldwork and academic study. Internship with community action agencies, political groups or elected officials. Prerequisite: consent of department chairperson.

**333. (SPSY 333) The Social Psychology of Politics** (3)
Political behavior viewed from a psychological and social psychological perspective.

**351. Constitutional Law** (3) fall
The law of the Constitution as expounded by the Supreme Court of the United States. Nature and origins of judicial review, distribution and scope of governmental powers, and economic regulation in a federal system. Detailed consideration of judicial policy decision-making processes. Whitcomb

**352. Civil Rights** (3) spring
A study of constitutional development in political and civil rights. Freedom of speech and of the press, religious freedom, due process of law and equal protection of the laws. Detailed consideration of constitutional issues concerning criminal procedure and racial discrimination. Whitcomb

**354. Administrative Law** (3)
The authority, procedures, and methods used by executive agencies in the administration of public policy. Analysis of the general problem of adjusting the administrative process to traditional constitutional principles. Barry

**355. Public Personnel** (3)
Problems in public personnel administration; the civil service and its reform; public employee unionism; due process within the organization; affirmative action; political neutrality of public servants. Barry

**359. U.S. Congress** (3)
The origins and development of Congress, formal and informal power of legislation and oversight. Party leadership and committees, House and Senate differences, and Congressional relations with the President, the bureaucracy and the Supreme Court. Davis

**360. Public Administration** (3)
The nature of administration; problems of organization and management; public personnel policies; budgeting and budgetary system; forms of administrative responsibility. Colon

**364. Issues in Contemporary Political Philosophy** (3)
Selected topics in contemporary political philosophy, such as the Frankfurt school, existentialism, legitimation, authenticity, participatory democracy, and the alleged decline of political philosophy. May be repeated for credit with the consent of the department chairperson. Matthews

**367. American Political Thought** (3)
A critical examination of American political thought from the founding of the Republic to the present. Writings from Madison, Hamilton, and Jefferson to Emma Goldman, Mary Daly, Malcolm X, Henry Kariel, and others will be discussed. Matthews

**368. Political Economy** (3)
Relationship of democratic politics to government and market, and of significance of economic power in the American polity. Economic rationale for the place of the market and economic institutions in polity. Comparison of economic approaches to public policy and organization, like public goods, market failure and collective action. Group mobilization and conflict, non-decisions, and symbolic action. Wurth

**371. Readings** (1-3)
Readings in political science assigned to properly qualified students in consideration of their special interest in particular political institutions and practices. Prerequisite: consent of the departmental chairperson.

**372. Readings** (1-3)
Continuation of Govt 371. Prerequisite: consent of the department chairperson.

**381, 382. Special Topics** (3)
A seminar on a topic of special interest in a particular political institution process, or policy. Prerequisite: consent of the department chairperson.

## For Graduate Students

The department of government offers a graduate program leading to the master of public administration and the master of arts degrees. The applicant for admission is required to demonstrate adequate undergraduate preparation, and may under certain circumstances be asked to submit Graduate Record Examination results.

### *Master of Arts*

The master of arts in government is a thirty-credit-hour program that can be accomplished in twelve months by full-time students. A comprehensive examination is required. The student may take twenty-four hours of course work and six hours of thesis or may take all thirty credit hours in course work. A graduate-level course in research methods is required of all candidates for the master of arts degree.

The master of arts program is intended for the student with liberal arts or natural science preparation who has a professional interest in government. The master of arts may be a preparatory step toward doctoral work at another institution or a final degree preparatory for teaching in junior and community colleges or research positions in governmental, institutional or industrial settings.

### *Master of Public Administration*

The master of public administration is a final degree emphasizing career preparation for governmental service. The program is designed to emphasize administration in all levels of governmental service—national, state, urban and municipal—and non-governmental service in quasi-public and academic organizations.

The program consists of four parts:

**core curriculum** (12 credit hours).
The core curriculum consists of courses in public management, legal foundations of public administration, governmental budgeting, and public policy.

**methodology and tools** (6 credit hours).
Two methodology courses, one dealing with basic methodological issues and techniques and another with field applications and data analysis, are required. Govt 421 and Govt 463 are designed to fulfill these requirements, but other courses may be substituted with the approval of the adviser. Also, a basic proficiency in accounting is required.

**public administration electives** (9 credit hours).
These electives, chosen in consultation with an adviser, may include courses from a number of departments such as government, economics, history, management, and social relations.

**internship** (3 credit hours).
This will be a specially arranged program. If a student has broad practical experience in public service, the internship requirement may be waived at the discretion of the graduate committee. A thesis-level essay is substituted.

The final requirement for the master of public administration is a comprehensive examination.

## Graduate Courses

**403. The American Polity (3)**
Integrative overview of the American polity's emphasis on national institutions: presidency, Congress, judiciary, party systems and their interrelations.

**405. The Budgetary Process (3)**
The public budgetary process: competition among interest groups, policy outcomes, intergovernmental relations, and consequences for policy implementation. Davis

**407. American Constitutional Development (3)**
The law of the Constitution as expounded by the Supreme Court of the United States. Nature and origins of judicial review, institutional aspects of separation of powers and federalism, economic regulation in a federal system, and political and civil rights. Detailed consideration of judicial policy-making processes and judicial biography. Whitcomb

**411. The Legal Foundations of Public Administration (3)**
The authority, procedures, and methods used by executive agencies in the administration of public policy and the general problem of adjusting the administrative process to traditional constitutional and legal principles. Barry

**413. Modern Political Philosophy (3)**
A study of selected modern political philosophers and their continuing effect on politics and political philosophy. Matthews

**415. State and Local Government (3)**
Comparative state government, urban politics, intergovernmental relations, regional and local government. Colon

**416. American Environmental Policy (3)**
Formation, implementation and impact of environmental policies in the U.S. An examination of the scope of environmental problems, the development of environment as an issue, the role of interest groups and public opinion, the policy-making process, and the various approaches to implementing environmental policy. Special attention to current issues and administrative approaches and to the distinctive character of environmental protection as a political issue. Wurth

**419. Theoretical Issues in American Politics (3)**
American contributions to main currents in political philosophy from colonial times to present. Matthews

**421. Research Methods (3)**
Research approaches, design techniques, statistical and non-statistical analysis, and computer applications. Davis

**424. Administrative Theory (3)**
Administrative theory and practice in both the public and nonpublic spheres in the United States; model building and field research emphasizing the concepts of public and private administrative systems. Colon

**425. Comparative Bureaucratic Systems (3)**
Bureaucracies and bureaucrats in Western and non-western political and cultural systems. Their role, power, internal dynamics and personal interactions; problems of policy implementation.

**430. Analytical Techniques for Public Administration (3)**
Introduction to models, concepts and techniques of decision theory, management science, managerial economics and systems theory. Emphasis on public sector applications.

**431. Public Management (3)**
The study of bureaucracy and problems of public and nonprofit organization and management; executive leadership; personnel management systems and regulatory administration. Colon

**432. Public Policy Process (3)**
Impacts of power relationships on selected public policy areas such as the military, agriculture, housing, environmental, energy, poverty, health, and taxation. May be repeated for credit. Olson

**434. Internship (3)**
Internship in private or public agency. May be repeated for credit.

**437. Teaching Internship (3)**
Supervised practice teaching at the college level.

**451. Comparative Politics (3)**
Theory and concepts in comparative politics. Analysis of applications in studies of Western and non-Western political systems.

**463. Methods of Urban Policy Analysis (3)**
Analysis of selected topics in urban or state/local policy. Applied research projects include computer-based statistical analysis. Prerequisite: Govt 421 or consent of the department chairperson. Morgan

**471. Seminar in Teaching Government (3)**
Theories and techniques of instruction, learning, evaluation, instructional design and innovation in the teaching of government. Prerequisite: permission of the department chairperson.

**481. Special Topics (3)**
Individual inquiry into some problem of government. Reading, field work, and other appropriate techniques of investigation. Conferences and reports. May be repeated for credit.

**482. Special Topics (3)**
Continuation of Govt 481.

# Greek

See listings under Classics.

# Hebrew

Modern Hebrew is taught in the Department of Modern Foreign Languages. Biblical Hebrew is taught in the Department of Religion Studies.

# History

**Professors.** Joseph A. Dowling, Ph.D. (N.Y.U.), *distinguished professor, chairman;* G. Mark Ellis, Ph.D. (Harvard); John H. Ellis, Ph.D. (Tulane); Steven L. Goldman, Ph.D. (Boston), *Andrew W. Mellon Distinguished Professor in the Humanities;* Lawrence H. Leder, Ph.D. (N.Y.U.); James S. Saeger, Ph.D. (Ohio State); William G. Shade, Ph.D. (Wayne State); Roger D. Simon, Ph.D. (Wisconsin); C. Leon Tipton, Ph.D. (Southern California).
**Associate professors.** Michael Baylor, Ph.D. (Stanford); Ian P.H. Duffy, D.Phil. (Oxford, England).
**Assistant professors.** Gail A. Cooper, Ph.D. (U.C., Santa Barbara); John K. Smith, Ph.D. (Delaware).
**Adjunct professors.** Curtis Keim, Ph.D. (Indiana); Winfred Kohls, Ph.D. (Berkeley).
**Adjunct assistant professor.** Stephen H. Cutcliffe, Ph.D. (Lehigh).

History is the study of human activities. As such, it encompasses not only events and public policy, but the whole sweep of cultural achievements—religion and philosophy, literature and art, economic and social life. Some of the most influential thinkers and public people of our time (Toynbee, Kennan, Churchill, Kennedy, among other) have studied contemporary problems by viewing the forces in the past that have shaped our world.

Students take courses in three culture areas, examining major developments in each in terms of cause and effect, the historian's main concern. These courses provide training in research, analysis of historical problems, and formulation of historical judgments, as well as in writing. History majors have the foundation for law school, government service, business careers, journalism, teaching, and graduate study.

Honors study in history is by invitation of the department in the student's junior year. The student is required to attain an average of 3.25 in history courses, and must demonstrate a special competence in history. Those interested in honors work are urged to consult the department chairman early in their junior year.

Honors students in history may plan special programs, including more in-depth study of two culture areas rather than three. They enroll for three to six hours of credit of unrostered history as part of their thirty-nine credit hours and complete in that course an honors thesis.

## *Distribution Requirements*

The major totals thirty-nine credit hours.

A history major meets the following distribution requirements: Hist. 11, 12, plus a maximum of nine additional hours in courses below 100; minimum of twelve hours in courses numbered above 200 not including Hist. 201 and 395; Hist. 201 or 395; maximum of eighteen hours of courses from any one group, and minimum of three hours from each group listed below.

**group a courses**

| | |
|---|---|
| Hist 7 | The Machine in America (3) |
| Hist 8 | History of Medicine in America (3) |
| Hist 9 | Survey of American History I (3) |
| Hist 10 | Survey of American History II (3) |
| Hist 53 | Religion and the American Experience (3) |
| Hist 111 | Engineering in the Modern World (3) |
| Hist 119 | Colonial America (3) |
| Hist 120 | Revolutionary America (3) |
| Hist 124 | Women in America (3) |
| Hist 131 | The Black Experience in America (3) |
| Hist 135 | United States, 1789-1840 (3) |
| Hist 136 | United States, 1840-1877 (3) |
| Hist 137 | United States, 1877-1920 (3) |
| Hist 138 | United States, 1920 to Present (3) |
| Hist 207 | Seminar in the History of Technology (3) |
| Hist 231 | American Diplomatic History (3) |
| Hist 260 | American Constitutional and Legal History (3) |
| Hist 310 | American Military History (3) |
| Hist 325 | American Social History, 1607-1877 (3) |
| Hist 326 | American Social History Since 1877 (3) |
| Hist 327 | American Intellectual History (3) |
| Hist 328 | American Intellectual History (3) |
| Hist 333 | American Urban History to 1880 (3) |
| Hist 334 | American Urban History, 1880 to Present (3) |
| Hist 338 | Psychohistory (3) |
| Hist 339 | Topics in American Public Health (3) |
| Hist 340 | Topics in American Medicine (3) |

**group b courses**

| | |
|---|---|
| Hist 11 | Survey of European History I (3) |
| Hist 12 | Survey of European History II (3) |
| Hist 15 | English History (3) |
| Hist 16 | English History (3) |
| Hist 21 | Ancient History (3) |
| Hist 22 | Ancient History (3) |
| Hist 149 | The Barbarian West (3) |
| Hist 150 | Medieval Civilization (3) |
| Hist 151 | Popular Religion in the Christian West (3) |
| Hist 154 | The Holocaust: History and Meaning (3) |
| Hist 157 | The Renaissance and Reformation (3) |
| Hist 158 | Early Modern Europe (3) |
| Hist 159 | Modern Europe (3) |
| Hist 160 | Modern Europe (3) |
| Hist 241 | Conservatism in the Modern Age (3) |
| Hist 243 | English History, 1471-1660 (3) |
| Hist 244 | English History 1660-1789 (3) |
| Hist 245 | Victorian Britain (3) |
| Hist 246 | Great Britain in the 20th Century (3) |
| Hist 261 | A History of Russia to 1855 (3) |
| Hist 262 | A History of Russia, 1855 to Present (3) |
| Hist 263 | Early Modern Germany, 1618-1848 (3) |
| Hist 264 | Modern Germany, 1848 to Present (3) |
| Hist 337 | History of Medical Thought (3) |
| Hist 355 | European Cultural History I (3) |
| Hist 356 | European Cultural History II (3) |
| Hist 357 | English Constitutional and Legal History to 1783 (3) |

**group c courses**

| | |
|---|---|
| Hist 5 | African Civilizations (3) |
| Hist 31 | History of Japanese Industrialization since 1800 (3) |
| Hist 49 | History of Latin America (3) |
| Hist 50 | History of Latin America (3) |
| Hist 61 | Survey of Middle Eastern History I (3) |
| Hist 62 | Survey of Middle Eastern History II (3) |
| Hist 171 | History of Southern Africa (3) |
| Hist 172 | History of West Africa (3) |
| Hist 173 | Topics in Middle Eastern History (3) |
| Hist 176 | Topics in East Asian History (3) |
| Hist 265 | Mexico and the Caribbean (3) |
| Hist 266 | Argentina, Brazil and Chile (3) |
| Hist 368 | Seminar in Latin American History (3) |

Hist 51, 300, 301, 371, 372, or provisional courses will be placed in one of the above groups in accordance with their contents and emphases.

History majors are encouraged to choose electives from among economics, English and American literature, government, international relations, philosophy, psychology, religion studies, and social relations. Students intending to do graduate work should acquire a reading knowledge of at least one foreign language, choosing languages appropriate to their area of concentration.

## *Minor Programs*

A student may establish a minor program in history that covers either a geographical, topical, or chronological interest (American, European, technological and medical, or twentieth century history, to mention a few possibilities). Each student's minor program is prepared in consultation with the chairman of the history department. *Advanced placement credit may not be used for the minor program.* The minor totals at least fifteen hours and conforms to the following pattern:

* six hours in courses numbered below 100

* maximum of six hours in 100 level courses
* minimum of three hours in courses numbered above 200

## Undergraduate Courses in History

Petitions are required for Freshmen to take 100-level or higher courses, and for Sophomores to take 200-level or higher courses.

**5. African Civilizations (3)**
Sub-Saharan Africa to present. Anthropological examination of traditional societies, chronology of indigenous African developments. Keim

**7. The Machine in America (3)**
American technology since colonial times. Changes in techniques and organization of processing, manufacturing, transportation and construction: consideration of social, cultural, and economic impact. Simon, Smith, Cooper

**8. History of Medicine in America (3)**
Institutional development of the American medical profession. John Ellis

**9. Survey of American History I (3) fall**
Social, economic, cultural and political institutions through Reconstruction, emphasizing their effects on public policy and culture.

**10. Survey of American History II (3) spring**
American culture, politics, and society from the late nineteenth century to the present, emphasizing the impact of industrialization.

**11. Survey of European History I (3) fall**
Development of European history from Rome to the 17th century. End of the ancient world, origins and growth of medieval civilization, the Renaissance and Reformation. Baylor

**12. Survey of European History II (3) spring**
European civilization from the 17th century to the end of World War II. Rise of scientific thought and the state system during the *ancient régime*, impact of the French and industrial revolutions, nationalism and liberalism, and two world wars and the end of European supremacy. Baylor

**15. English History (3) fall**
The history of England to 1688. The origins of representative government, the development of English social institutions, the unification of England, and the Renaissance and Reformation in England. Duffy

**16. English History (3) spring**
English political and social institutions from 1688 to the present. The evolution of parliamentary government, the rise of modern parties, the industrial revolution, and recent social philosophies. Duffy

**21. (Clss 21) Ancient History (3) fall**
The development of civilization from paleolithic times to the world empire of Alexander the Great. The social, economic, religious, philosophic, artistic, and literary development of the ancient world; the origin of political institutions. Phillips

**22. (Clss 22) Ancient History (3) spring**
Continuation of Greek 21, The Hellenistic Age. Rome from its origin to 395 A.D. Phillips

**31. History of Japanese Industrialization since 1800 (3)**
The late Tokugawa economic development, rise of an entrepreneurial class, importation of western technology, and the rise of social, political, and economic institutions which support industrial growth. Cooper

**49. History of Latin America (3) fall**
Spanish and Portuguese colonization of America and the struggles for independence, preceded by a brief view of the ancient American civilizations and Iberian backgrounds. Saeger

**50. History of Latin America (3) spring**
Continuation of Hist 49. The development of the Latin American nations in the nineteenth and twentieth centuries. Saeger

**51. Freshman Seminar (3)**
An intensive analysis of a particular period, problem or area of history, emphasizing readings, discussions and reports. The topics and instructor vary each semester. Open by invitation to students with advanced placement credit in history or equivalent background, or upon application to the chairman of the department.

**53. (Rel 53) Religion and the American Experience (3) fall**
The historical development of major religious groups in this country from colonial times to the present. Their place in social and political life, and the impact of the national experience upon them. Emphasis on religious freedom and pluralism, and the church-state relationship.

**61. Survey of Middle Eastern History I (3) fall**
Social, economic, cultural, and political history of Islam from Mohammed to the mid-18th century.

**62. Survey of Middle Eastern History II (3) spring**
Continuation of History 61, emphasizing the formation of Islamic states and political events of the 20th century.

**103. (Rel 103) Christianity I: Early and Medieval (3) fall**
Historical and theological investigations of Orthodox and Catholic traditions. Issues of doctrine, authority, community and liturgy.

**111. Engineering in the Modern World (3)**
Roles played by engineers and engineering in the modern world, focusing on major achievements and failures, prominent engineers, and evolution of the profession. Smith

**119. Colonial America (3) fall**
Founding and growth of colonies in North America through circa 1750. Attention will be paid to motives behind European expansion as well as to developments in the colonies. Leder

**120. Revolutionary America (3) spring**
American political, economic and cultural development from the mid-eighteenth century through the adoption of the Federal Constitution. Leder

**124. Women in America (3)**
Roles of women in American society from colonial to present times: attitudes toward women, female sexuality, women's work, and feminism. Shade

**131. The Black Experience in America (3)**
Black subculture in America from the colonial period to the present, emphasizing the struggle for emancipation and equal rights. Topics include: racialism, slavery, Reconstruction, urbanization protest movements, and the 'Second Reconstruction.' Shade

**135. United States, 1789-1840 (3)**
The American political system from the Constitution through Jacksonianism. Special emphasis upon the first and second party systems and the democratization of American political culture. Shade

**136. United States, 1840-1877 (3)**
Civil War and Reconstruction, emphasizing the causes of the Civil War, its impact upon American society and politics, and problems of postwar reconstruction. Shade

**137. United States, 1877-1920 (3)**
Political, economic and social responses to industrial America. The rise of the Populist and Progressive movements, coming of World War I, and postwar developments. John Ellis

**138. United States, 1920 to Present (3)**
American institutions in the modern era, emphasizing critical changes of the 1920s, the Crash of 1929, the New Deal, World War II, and later political, social and economic events. Dowling

**145. (STS 145) Introduction To the History of Science** (3)
The history of modern science, primarily physical and biological, with emphasis on the development of major theoretical models since the seventeenth century. Goldman

**149. The Barbarian West** (3) fall
Merger of Greco-Roman, Germanic and Christian institutions and culture in Western Europe to mid-eleventh century. Evolution of the church, feudalism and manorialism, and the foundations of the Carolingian and Holy Roman empires. Tipton

**150. Medieval Civilization** (3) spring
Formation and development of western culture to about 1400. Rise of universities and towns, legal development and origins of representative government, origins of nation-states, scholasticism and decline of the medieval church. Tipton

**151. Popular Religion in the Christian West** (3)
Cult Christianity as understood and practiced by medieval people, including residual paganism, superstitions, cult of saints and relics, heresy, witchcraft and other religious elements of mass appeal. Tipton

**154. (Rel 154) The Holocaust: History and Meaning** (3) spring
The Nazi Holocaust in its historical, political and religious setting. Emphasis upon the moral, cultural and theological issues raised by the Holocaust.

**157. (Rel 157) The Renaissance and Reformation** (3) fall
Transition from medieval to early modern society: decline of medieval civilization; political, social and cultural changes of the Renaissance; development of Protestantism and impact on European politics and culture. Baylor

**158. Early Modern Europe** (3) spring
Transformation of European civilization from the 30 Years War to the outbreak of the French Revolution. Origins and development of the European state system; absolutism; commercial expansion and competition for empire; science; the Enlightenment; impact on European culture and politics. Baylor

**159. Modern Europe** (3) fall
Revolutions and reactions in Western Europe from 1789 to 1870. The rise and spread of liberalism and the origins of socialism. Duffy

**160. Modern Europe** (3) spring
Contemporary Europe; the origins and consequences of two world wars; the rise of revolutionary governments in Italy, Germany and Russia. Duffy

**171. History of Southern Africa** (3)
Africa south of the Zambesi especially after arrival of Europeans. Portuguese contact with the Bakongo, effect of missionaries, conflicts between British and Boers, exploitation of minerals, apartheid, American policy, and socialism in Angola and Mozambique. Keim

**172. History of West Africa** (3)
Crop and animal domestication, rise and fall of western Sudan and forest empires, slavery and slave trade, the Fulani Jihads, legitimate trade, colonialism, nationalism, and uncertainty since independence. Keim

**173. Topics in Middle Eastern History** (3)
Problems in major societies of the contemporary Middle East.

**176. Topics in East Asian History** (3)
Topics in major societies of East Asia.

## *For Advanced Undergraduates And Graduate Students*

**201. Historical Perspectives** (3) spring
Methodologies and interpretations of Western historians from ancient times to the present. G. Mark Ellis

**202. Problems in History** (3)
Intensive study of a particular historical event, topic or time period. Topic will vary.

**215. (Clss 215) Decline and Fall of the Roman Empire** (3)
Political, social, and economic history of the Roman Empire, A.D. 117-A.D. 565. Romanization of the provinces, diffusion of Christianity, and special attention to transformation to medieval period. Includes readings in translation of primary sources. Phillips

**220. (Clss. 220) Golden Age of Greek Democracy**
Greek history of the seventh through fifth centuries B.C. Emphasis on the contrasting political and social systems of Athens and Sparta with consideration of related economic and military history. Attention to art, gender, literature, religion. Discussion and lectures; papers.

**231. American Diplomatic History** (3) fall
Late 18th-century diplomatic ideas, their development and application through the 19th century, and their transformation in the 20th century as a result of changing needs and responsibilities. Leder

**241. Conservatism in the Modern Age** (3)
Conservative thought from the eighteenth century to present, including Burke, romantic conservatism, classical liberalism, and the response to industrialism and technology. Tipton

**243. English History, 1471-1660** (3) fall
England under the Tudor monarchy and the problems facing its successors culminating in the civil wars and Interregnum. Political, economic, intellectual and religious developments of the period. G. Mark Ellis

**244. English History 1660-1789** (3) spring
Constitutional monarchy from the Stuart Restoration to the French Revolution. English civilization in an age of oligarchy, especially the political, social, economic and intellectual sectors. G. Mark Ellis

**245. Victorian Britain** (3) fall
Development of democracy, liberalism, religious ferment, industrialization, class conflict, socialism, and empire in Victorian Britain. Duffy

**246. Great Britain in the 20th Century** (3) spring
Effects of world wars, loss of great power status, economic decline, social conflict, welfare state, modern political parties, Irish problem on 20th century Britain. Duffy

**260. American Constitutional and Legal History** (3) fall
Adoption of the federal constitution and its modification and expansion: Anglo-American legal tradition and its transformation. Leder

**261. A History of Russia to 1855** (3) fall
Major cultural, social, and political traditions of the Russian people. Kohls

**262. A History of Russia, 1855 to Present** (3) spring
The great Reforms, collapse of Tsarist absolutism, revolution of 1917, and formulation and consolidation of the Soviet dictatorship. Kohls

**263. Early Modern Germany, 1618-1848** (3) fall
Germany from the Reformation to the Revolution of 1848. Origins and development of absolutism, transformation of German society and thought, Austro-Prussian dualism, impact of the French Revolution and defeat of early liberalism. Baylor

**264. Modern Germany, 1848 to Present** (3) spring
German nationalism and Prussian unification, socio-economic and cultural change in the Second Empire, First World War and the Weimar Republic, origins and growth of fascism, the Third Reich and post-totalitarian Germany. Baylor

**265. Mexico and the Caribbean** (3)
Emphasis on Mexico and Cuba from the era of Bourbon reforms

through the wars of independence to the twentieth century revolutions. Saeger

**266. Argentina, Brazil and Chile (3)**
Eighteenth-century Spanish imperial readjustments, independence, the emergence of new societies, twentieth-century extremist movements, and the problems of developing nations. Saeger

**301. Seminar in the History of Technology (3)**
Readings and research in the history of technology and engineering education. Students will pursue topics of individual interest around a general theme. Simon, Smith, Cooper

**310. American Military History (3)** spring
The American military tradition from colonial times to the present. America's wars and the development and operation of military institutions within the political, economic, ideological, and technological milieu of American society. Saeger

**325. (Soc 325) American Social History, 1607-1877 (3)** fall
Social change from early agrarian communities to beginnings of industrialism, emphasizing socio-economic class, family structure, and treatment of women and minority groups. Shade

**326. (Soc 326) American Social History Since 1877 (3)** spring
Changing role of women, minorities, and the family during the industrial era. Development of the modern class structure and the impact of the welfare state. Simon

**327. American Intellectual History (3)** fall
Development of political, social and religious ideas in America from the colonial period to the Civil War. Dowling

**328. American Intellectual History (3)** spring
Economic, political and religious thought in industrial America, 1860 to present. Dowling

**333. American Urban History to 1880 (3)** fall
Planning and design of colonial and frontier cities. Impact of transportation innovations and industrialization, emergence of a national system of cities. Internal problems of early industrial cities: housing, transportation, public health, crime, social mobility. Simon

**334. American Urban History, 1880 to Present (3)** spring
Physical expansion of the industrial city and its relationship to current urban problems. Suburbanization, development of the central business district, reforms in housing and public health, rise of ghettoes, emergence of the city planning profession and the idea of 'new town,' impact of the New Deal and 'urban renewal.' Simon

**337. History of Medical Thought (3)**
From prehistory to present: shamanism and healing, Greco-Roman medicine, Paracelsus and Harvey, and the germ theory of disease. John H. Ellis

**338. Psychohistory (3)** spring
Uses of psychology in history and biography; exploration of problems of methodology, verification of evidence, conceptual frameworks and theories of personality; potentialities and limitations of psychological investigation as an historical technique. Dowling

**339. Topics in American Public Health (3)**
Reading and research on topics in the history of the American public health movement. Prerequisite: Hist 8. J.H. Ellis

**340. Topics in American Medicine (3)**
Reading and research on topics in the history of American medicine. Prerequisite: Hist 8. J.H. Ellis

**355. (Rel 355) European Cultural History I (3)** fall
Major developments in European culture from the late Middle Ages through the 17th century. Late scholasticism, humanism and the Renaissance, varieties of Protestantism, origins of modern science. Baylor

**356. European Cultural History II (3)** spring
Transformation of European culture from the 18th century to the present. The Enlightenment, cultural impact of the French and industrial revolutions, romanticism and ideologies of the 19th century, contemporary European thought. Baylor

**357. English Constitutional and Legal History to 1783 (3)** spring
Origins and development of government, administration and law from Anglo-Saxon times to 1783, emphasizing common-law institutions, practices and procedures. Duffy

**368. Seminar in Latin American History (3)**
Readings and individual investigation of selected topics. Saeger

**371. Special Topics in History (1-3)**
Intensive study in an area of history not adequately covered in currently listed offerings. The course may be administered as a reading program or otherwise as may seem best to meet the needs of students of unusual ability and adequate preparation. Prerequisite: consent of the department chairman.

**372. Special Topics in History (1-3)**
Continuation of History 371. Prerequisite: consent of the department chairperson.

**395. Quantitative Methods in Historical Studies (3)**
Historical uses and methods of quantitative analysis, including the application of descriptive statistics, statistical inference, and computer technology to a variety of problems drawn from European, American and Latin American history. Shade

## *For Graduate Students*

Linderman Library is especially rich in materials for advanced study and research in history, and the department of history offers programs leading to master of arts and doctor of philosophy degrees. Graduate programs provide intensive and specialized study, and the policy of limited enrollment permits close relations between faculty and students.

Admission to graduate study in history is competitive and dependent upon the applicant's undergraduate preparation and record, recommendations, and Graduate Record Examination scores. Besides general requirements for the Graduate School, the following special requirements apply to graduate study in history.

## *Master of Arts*

There are two masters programs. Under plan I, a candidate may earn the degree by successfully completing twenty-four hours of approved course work and submitting a satisfactory thesis. Those continuing toward a doctorate elect plan I. Candidates declaring plan II do not write a thesis, but take thirty hours of course work in and pass examinations in two fields chosen from American, British, European and Latin American history, and history of science and technology. Candidates in either plan are required to maintain a 3.0 average in all graduate work and to take at least one research seminar.

## *Doctor of Philosophy*

Candidates for the doctor of philosophy in history must maintain a 3.25 history average and a 3.0 over-all average on all graduate work taken at Lehigh or elsewhere. Students entering with a master's degree take a qualifying examination before beginning their second semester at Lehigh. During the second semester, doctoral students select four history fields and one outside field and prepare themselves for written and oral examinations in those fields. An original dissertation is required and may be written only in a primary field.

**Primary fields.** Primary fields are Colonial America, nineteenth-century America, twentieth-century America, modern Britain, and the history of science, technology and medicine.

**Other fields.** Other fields of specialization are Medieval-Renaissance, Modern Europe to 1789, Modern Europe Since 1789, and Latin America.

**Language requirements.** The qualifying examination in one language must be passed before beginning course work beyond the master's degree in order that the language may be used in doctoral

course work. The candidate's special committee, appointed by the chairman of the department, will designate any additional languages for the student, if needed. Languages normally chosen are French, Spanish, Italian, German or Russian. Graduate-level competence in statistical methods and computer application are acceptable as replacement for a foreign language. All graduate majors take Hist 401 and either 404 or 405. All Ph.D. candidates must take 18 hours of directed readings and two research seminars. More detailed regulations are given in the *Handbook for Graduate Work in History,* available in the history department office.

**401. Methods in Historical Research (3)** fall
Techniques of research in history: training in the critical handling of documentary materials, in measuring the value of evidence, and in formal presentation of the results of research. Required of all graduate students in history. Tipton

**404. Historiography: Europe (3)**
The approach, methods and interpretations of the leading historians of Europe.

**405. Historiography: America (3)**
The approach, methods and interpretations of the leading historians of America.

**442. Readings in American History (3)**
Study in small groups under the guidance of a faculty member of the literature of a particular period, problem, or aspect of American history. May be repeated for credit with permission of the department chairman.

**443. Readings in English History (3)**
Study in small groups, under the guidance of a faculty member, of the literature of a particular period, problem, or area of English history. May be repeated for credit with permission of the department chairman.

**444. Readings in Latin American History (3)**
Study in small groups, under the guidance of a faculty member, of the literature of a particular period, problem, or area of Latin American history. May be repeated for credit with permission of the department chairman.

**445. Readings in History of Science and Technology (3)**
Study in small groups, under the guidance of a faculty member, of themes in the history of science and technology. May be repeated for credit with permission of the department chairman.

**447. Readings in European History (3)**
Study in small groups, under the guidance of a faculty member, of the literature of a particular period, problem or aspect of European history. May be repeated for credit with permission of the department chairman.

**452. Research in American History (3)**
An intensive research seminar on a phase of American history. May be repeated for credit with permission of the department chairman.

**453. Research in English History (3)**
An intensive research seminar on a phase of English history. May be repeated for credit with permission of the department chairman.

**454. Research in Latin American History (3)**
An intensive research seminar on a phase of Latin American history. May be repeated for credit with permission of the department chairman.

**455. Research in History of Science and Technology (3)**
An intensive research seminar on a phase or aspect of the history of science and technology. May be repeated for credit with permission ofthe department chairman.

**457. Research in European History (3)**
An intensive research seminar on phase of European history. May be repeated for credit with permission of the department chairman.

# Industrial Engineering

**Professors.** Marlin U. Thomas, Ph.D. (Michigan), *chairperson;* Mikell P. Groover, Ph.D. (Lehigh); George E. Kane, M.S. (Lehigh); John C. Wiginton, Ph.D. (Carnegie-Mellon); Emory W. Zimmers, Jr., Ph.D. (Lehigh).
**Associate professors.** John W. Adams, Ph.D. (North Carolina); Nicholas G. Odrey, Ph.D. (Penn State); Louis J. Plebani, Ph.D. (Lehigh); George R. Wilson, Ph.D. (Penn State).
**Assistant professors.** G. Sathyanarayanan, Ph.D. (Michigan Tech); Robert H. Storer, Ph.D. (Georgia Tech); Gregory L. Tonkay, Ph.D. (Penn State); Szu-Yung David Wu, Ph.D. (Penn State).

The curriculum is designed with the principal aim of industrial engineering in view, which is the design, improvement, and installation of integrated systems of people, materials, and equipment for operations by the application of the principles of the mathematical, physical, and behavioral sciences.

Throughout the program there is an integrated series or sequence in the major field that includes not only basic and fundamental courses but specialized courses as well, in the fields of production planning and control, quality control, computer-integrated manufacturing, production engineering, information systems, robotics, and operations research. These specialized courses reflect the impact of recent developments in operations research, information processing, and manufacturing systems.

## *Career Opportunities*

There is a growing tendency on the part of industries to select young people from their engineering departments for managerial positions. Because of this the industrial engineering courses are oriented to the principles of scientific management to enable the industrial engineering graduate to accept and succeed in these opportunities.

It is the aim of the industrial engineering program to develop the potential manager for either the manufacturing or service industries as well as the government agency, a graduate well grounded in the fundamentals of science, trained in the principles of engineering analysis and design, and thus prepared to practice the profession of industrial engineering.

## *Physical Facilities*

The manufacturing technology laboratory affords an opportunity to students for gaining understanding and skills in manufacturing processes, experimental design, collection of data, manufacturing systems, and instrumentation calibration.

The computer-integrated manufacturing (CIM) laboratory presents the student with an opportunity to use a mini-computer and microprocessors for data collection, process design, and process control.

The information systems laboratory serves the student by presenting opportunities in interactive programming, data processing, and data base systems.

The microprocessor laboratory serves the student by providing an opportunity to gain understanding and design skill in the application of microprocessors to industrial engineering situations.

An interdisciplinary robotics laboratory provides students with the opportunity to gain first-hand experience with the various types of robots and to gain skill in planning their use.

The work systems laboratory affords the opportunity to students to analyze and plan human activities at both individual work stations and in the monitoring of multiple machine stations. This is accomplished in part through the use of microprocessor-driven simulators.

Considerable use is made of the university Computing Center facilities in all levels of course work.

## *Special Programs*

**Electives within the industrial engineering curriculum.** The industrial engineering curriculum offers an extensive program of electives that permits the student to shape a program of study that

reflects personal interests. The over-all program of electives is comprised of:

15 credit hours of engineering science electives
9 credit hours of advanced industrial engineering electives
15 credit hours of general studies electives
6 credit hours of free electives

**Use of electives to emphasize an area within industrial engineering.** Lehigh's industrial engineering department emphasizes four areas: information systems, manufacturing systems, operations research, and operations management. Students may choose their electives to emphasize one area. Examples of using the elective program for this purpose are as follows:

## *Information Systems Emphasis*

suggested course work

*engineering science* (15 credit hours)

| | |
|---|---|
| CSc 33 | Principles of Computer Engineering (4) |
| CSc 261 | Discrete Structures (3) |
| ECE 315 | Principles of Computer Software (3) |
| CE 121 | Mechanics of Fluids (3) |
| ME 104 | Thermodynamics I (3) |

*IE electives* (9 credit hours)

| | |
|---|---|
| IE 307 | Advanced Systems Analysis and Design (3) |
| IE 310 | Database Analysis and Design (3) |
| IE 345 | Manufacturing Information Systems (3) |

*General Studies* (15 credit hours)

| | |
|---|---|
| Phil 13 | Practical Logic (3) |
| Jour 123 | Basic Science and Technical Writing (3) |
| Jour 311 | Science and Technical Writing (3) |
| Anth 131 | Science, Technology and Society (3) |
| Psyc 1 | Introduction to Psychology (3) |

*free electives* (6 credit hours)

| | |
|---|---|
| Spch 31 | Business and Professional Speaking (3) |
| IE 334 | Organizational Planning and Control (3) **or** |
| IE 341 | Data Communication Systems Analysis and Design (3) |

## *Manufacturing Systems Emphasis*

suggested course work

*engineering science* (15 credit hours)

| | |
|---|---|
| Mech 1, 11 | Statics and Mechanics of Materials (6) |
| Mat 213 | Materials Systems Analysis (3) |
| CE 121 | Mechanics of Fluids (3) |
| ME 104 | Thermodynamics I (3) |

*IE electives* (9 credit hours)

| | |
|---|---|
| IE 324 | Industrial Robotics (3) |
| IE 340 | Production Engineering (3) |
| IE 342 | Computer Integrated Manufacturing (3) **or** |
| IE 343 | Microprocessor Systems in IE (3) |

*General Studies* (15 credit hours)

| | |
|---|---|
| Anth 131 | Science, Technology and Society (3) |
| Psyc 1 | Introduction to Psychology (3) |
| Eco 105 | Intermediate Microeconomic Analysis (3) |
| Eco 335 | Labor Economics (3) |
| Hist 7 | The Machine in America (3) |

*free electives* (6 credit hours)

| | |
|---|---|
| Spch 31 | Business and Professional Speaking (3) |
| IE 332 | Product Quality (3) |

## *Operations Research Emphasis*

suggested course work

*engineering science* (15 credit hours)

| | |
|---|---|
| CSc 261 | Discrete Structures (3) |
| CE 121 | Mechanics of Fluids (3) |
| Mech 1, 11 | Statics and Mechanics of Materials (6) |
| ME 104 | Thermodynamics I (3) |

*IE electives* (9 credit hours)

| | |
|---|---|
| IE 305 | Simulation (3) |
| IE 316 | Advanced Operations Research Techniques (3) |
| IE 332 | Product Quality (3) |

*General Studies* (15 credit hours)

| | |
|---|---|
| Phil 13 | Practical Logic (3) |
| Phil 214 | Logical Theory (3) |
| Anth 131 | Science, Technology and Society (3) |
| Hist 7 | The Machine in America (3) |
| Eco 105 | Intermediate Microeconomic Analysis (3) |

*free electives* (6 credit hours)

| | |
|---|---|
| Spch 31 | Business and Professional Speaking (3) |
| IE 307 | Advanced Systems Analysis and Design (3) |

## *Operations Management Emphasis*

suggested course work

*engineering science* (15 credit hours)

| | |
|---|---|
| Mech 1, 11 | Statics and Mechanics of Materials (6) |
| Mat 213 | Materials Systems Analysis (3) |
| CE 121 | Mechanics of Fluids (3) |
| ME 104 | Thermodynamics I (3) |

*IE electives* (9 credit hours)

| | |
|---|---|
| IE 305 | Simulation (3) |
| IE 342 | Computer Integrated Manufacturing (3) |
| IE 345 | Manufacturing Information Systems (3) |

*General Studies* (15 credit hours)

| | |
|---|---|
| Eco 105 | Intermediate Microeconomic Analysis (3) |
| Eco 229 | Money and Banking (3) |
| Eco 335 | Labor Economics (3) |
| Hist 7 | The Machine in America (3) |
| Psyc 1 | Introduction to Psychology (3) |

*free electives* (6 credit hours)

| | |
|---|---|
| Spch 31 | Business and Professional Speaking (3) |
| Fin 225 | Business Finance (3) |

## *Options Through Electives*

The following section shows how use of electives can help students achieve education goals.

**To pursue a technical minor.** Students may elect to use their electives to obtain a technical minor. A technical minor requires a minimum of fifteen credit hours. The engineering minors available to industrial engineering majors include molecular biophysics, chemical processing, computers, fluid mechanics and solid mechanics. The courses taken to satisfy the minor are part of the elective program and do not require an academic overload.

**To pursue a nontechnical minor.** Students may choose to pursue nontechnical minors ranging from classics to economics. A nontechnical minor requires a minimum of fifteen credit hours. The courses taken to satisfy the nontechnical minor are part of the elective program and do not require an academic overload.

**Industrial Engineering/Master of Business Administration** program. Students in the Industrial Engineering Curriculum may pursue a special IE/MBA program by completing the 42 hours of courses listed below in the suggested sequence while completing their major in one of the BS programs in the college during their first four years. At the end of this period, if they are admitted to the Graduate School, they may be granted their MBA degree upon completion of

an additional 39 hours of course work. This can usually be accomplished in two regular semesters and two summer sessions.

All courses listed below under Other Required Courses must have a grade of B− or better in order to be credited toward the MBA program.

The following comprise the required courses during the four years in the college:

*required background courses*

| | |
|---|---|
| Eco 1 | Economics (4) |
| Math 21 | Analytic Geometry and Calculus I (4) |
| Math 22 | Analytic Geometry and Calculus II (4) |
| IE 224 | Information Systems Analysis and Design (3) |

*other required courses*

| | |
|---|---|
| IE 121 | Applied Engineering Statistics (3) |
| Acct 51 | Introduction to Financial Accounting (3) (Free Elective) |
| Acct 52 | Introduction to Managerial Accounting (3) (Substituted for Acct 108) |
| Eco 105 | Intermediate Microeconomic Analysis (3) (General Studies Elective) |
| Eco 119 | Intermediate Macroeconomic Analysis (3) (General Studies Elective) |
| Acct 234 | Cost Accounting (3) (Free Elective) |
| IE 221 | Operations Research - Probabilistic Models (3) |
| Law 201 | Legal Environment of Business (3) (Free Elective) |
| Eco 229 | Money and Banking (3) (General Studies Elective) |

Students who do not take Acct 52 and Acct 324 as undergraduates will be required to take Acct 413 as part of their MBA course work.

## *Major Requirements*

**freshman year** see page 37

**sophomore year, first semester** (16 credit hours)

| | |
|---|---|
| IE 111 | Engineering Probability and Statistics (3) |
| IE 112 | Computer Graphics (1) |
| Math 23 | Analytic Geometry and Calculus III (4) |
| Phys 21, 22 | Introductory Physics II and Laboratory (5) |
| | engineering science elective (3) |

**sophomore year, second semester** (17 credit hours)

| | |
|---|---|
| IE 121 | Applied Engineering Statistics (3) |
| IE 122 | Software Tools (1) |
| IE 124 | Engineering Economy and Decision Analysis (3) |
| | engineering science elective (3) |
| Mat 63 | Engineering Materials and Processes (3) |
| Eco 1 | Economics (4) |

**junior year, first semester** (16 credit hours)

| | |
|---|---|
| IE 115 | Fundamentals of Modern Manufacturing (3) |
| IE 116 | Manufacturing Laboratory (1) |
| IE 221 | Operations Research - Probabilistic Models (3) |
| Math 205 | Linear Methods (3) |
| Acct 108 | Fundamentals of Accounting (3) |
| | engineering science elective (3) |

**junior year, second semester** (17 credit hours)

| | |
|---|---|
| IE 131 | Work Systems and Facilities Planning (3) |
| IE 132 | Work Systems and Facilities Planning Laboratory (1) |
| IE 222 | Operations Research - Deterministic Models (3) |
| IE 224 | Information Systems Analysis and Design (3) |
| ECE 81 | Principles of Electrical Engineering (4) |
| | general studies elective (3) |

**summer**

| | |
|---|---|
| IE 100 | Industrial Employment (0) |

**senior year, first semester** (18 credit hours)

| | |
|---|---|
| IE 251 | Production and Inventory Control (3) |
| IE | elective (3) |
| | general studies elective (6) |
| | engineering science elective (3) |
| | elective (3)* |

**senior year, second semester** (18 credit hours)

| | |
|---|---|
| IE 154 | Senior Project (3) |
| IE | electives (6) |
| | general studies elective (3) |
| | engineering science elective (3) |
| | elective (3)* |

For engineering science electives, see the approved list in the industrial engineering office.

*please refer to description of normal program (page 36).

## Undergraduate Courses

**100. Industrial Employment (0)**
Usually following the junior year, students in the industrial engineering curriculum are required to do a minimum of eight weeks of practical work, preferably in the field they plan to follow after graduation. A report is required. Prerequisite: Sophomore standing.

**111. Engineering Probability and Statistics (3)** fall
Random variables, probability models and functions, and expected values. Statistical inference, estimation, hypothesis testing, and goodness of fit. Prerequisite: Math 22.

**112. Computer Graphics (1)** fall
Introduction to interactive graphics and construction of multi-view representations in two- and three-dimensional space. Applications in industrial engineering. Prerequisite: Sophomore standing in industrial engineering, Engr. 1.

**115. Fundamentals of Modern Manufacturing (3)** fall
Study of modern production methods. Machining and other metal working processes, electrical and electronics manufacturing, and nontraditional processing. Introduction to automation, numerical control, and industrial robots. Prerequisite: Mat 63.

**116. Manufacturing Laboratory (1)** fall
Laboratory exercises and experiments in manufacturing processes and systems. Prerequisite: IE 115, either previously or concurrently.

**121. Applied Engineering Statistics (3)** spring
The application of statistical techniques to solve industrial problems. Topics include regression and correlation, analysis of variance, quality control, and reliability. Prerequisite: IE 111 or Math 231.

**122. Software Tools (1)** spring
Introduction to application software tools, including word processing, spreadsheets, and statistical packages. Problems for solution will be drawn from other courses in the sophomore program. Prerequisites: Engr. 1; IE 121, 124 concurrently.

**124. Engineering Economy and Decision Analysis (3)** spring
Economic analysis of engineering projects; interest rate factors, methods of evaluation, depreciation, replacement, break-even analysis, after-tax analysis. Decision-making under certainty and risk. Prerequisite: IE 111 or Math 231, either previously or concurrently.

**131. Work Systems and Facilities Planning (3)** spring
Techniques of methods analysis, work measurement, and facilities design. Man-machine systems, assembly systems, operations analysis, time study, predetermined time systems, work sampling,

incentive systems, plant layout, and materials handling. Prerequisite: IE 121, either previously or concurrently.

**132. Work Systems and Facilities Planning Laboratory (1)** spring
Laboratory exercises and projects in methods analysis, operations analysis, plant layout, and related topics. Prerequisite: IE 131, either previously or concurrently.

**154. Senior Project (3)** fall and spring
The use of industrial engineering techniques to solve a major problem in either a manufacturing or service environment. Problems are sufficiently broad to require the design of a system. Consideration of human factors in the system design. Laboratory. Prerequisite: Senior standing in industrial engineering.

**168. Production Analysis (3)** fall and spring
A course for the engineering student not majoring in industrial engineering. Engineering economy; application of quantitative methods to facilities analysis and planning, operations planning and control, work measurement and scheduling, and operating systems analysis. Prerequisites: Math 22 or 42; Eco 1.

## For Advanced Undergraduates and Graduate Students

**221. Operations Research - Probabilistic Models (3)** fall
Probabilistic models in operations research. Topics include queueing theory, probabilistic inventory models, Markov analysis, and simulation, including use of a simulation language. Prerequisite: IE 111 or Math 231.

**222. Operations Research - Deterministic Models (3)** spring
Deterministic models in operations research. Topics include linear programming, integer programming, networks, dynamic programming, and classical optimization. Prerequisite: Math 205.

**224. Information Systems Analysis and Design (3)** spring
Study of information systems development to include design, implementation, evaluation, and management based on a standard development life cycle methodology. Structured analysis and design techniques are introduced. Prerequisites: Junior standing in Industrial Engineering, IE 122 and Acct 51 or 108.

**251. Production and Inventory Control (3)** fall
Techniques used in the planning and control of production and inventory systems. Topics include forecasting, inventory models, operations planning, and scheduling. Prerequisite: IE 221, either previously or concurrently, and IE 121, IE 222.

**305. Simulation (3)**
Applications of discrete and continuous simulation techniques in modeling industrial systems. Simulation using a high level simulation language. Design of simulation experiments. Prerequisites: IE 221 and IE 222.

**307. Advanced Systems Analysis and Design (3)** spring
Study of advanced techniques and their application in the analysis and design of information systems. Emphasis is placed on tools and techniques used for structured analysis and design, and on prototyping of systems. Prerequisite: IE 224 or 309 or equivalent.

**309. Introduction to Information Systems (3)** fall
Study of information systems analysis and design with emphasis on management issues. Interfaces between information systems and databases and data communications are examined. Effects of information systems on organizational relationships are considered. Example information system will be designed and implemented. Prerequisite: Engr. 1 or equivalent. Not available to Industrial Engineering undergraduates.

**310. Database Analysis and Design (3)** spring
Conceptual analysis of data is considered through data structures and models. Logical design of databases is studied in the context of the relational model of data. Prerequisite: IE 224 or 309 or equivalent.

**316. Advanced Operations Research Techniques (3)**
A survey of advanced topics in operations research. Topics include advanced linear programming, dynamic programming, integer programming, Markov chains, forecasting and elementary nonlinear programming algorithms. Prerequisites: IE 221 and IE 222.

**319. Material Handling and Facilities Planning (3)**
Material handling systems, storage systems and automatic identification. Facilities planning including layout planning and facility location. Prerequisite: IE 131 or consent of department chair.

**321. Experimental Industrial Engineering (1-3)**
Experimental projects in selected fields of industrial engineering, approved by the instructor. A written report is required. May be repeated for academic credit.

**324. Industrial Robotics (3)**
Introduction to robotics technology and applications. Topics include robot anatomy, controls, sensors, programming, work cell design, part handling, welding, and assembly. Laboratory exercises. Prerequisites: Mech 1, Math 205.

**332. Product Quality (3)**
Inspection for process control and product acceptance. Performance and life tests, increased severity. Evaluation of design in structure, process and performance specifications. Liability, unlikely events. Calibration versus data adjustment, traceability. Quality Assurance organization. Military standards and Federal regulations. Prerequisite: IE 121.

**334. Organizational Planning and Control (3)** fall
Design of organization and procedures for managing functions of industrial engineering. Analysis and design of resources planning and control, including introduction of change in man-machine systems; manpower management and wage administration. Prerequisite: IE 131 or 168.

**340. Production Engineering (3)** fall
Develop plans of manufacturing for discrete parts. Product design analysis and engineering materials utilization. Economic analysis of process design alternatives. Introduction to mechanization and automation. Term project. Laboratory. Prerequisite: IE 115.

**341. Data Communication Systems Analysis and Design (3)**
Study of data communications systems analysis and design to provide a basis for designing, implementing, and managing information systems employing wide and/or local area networks. Prerequisite: IE 224 or 309 or equivalent.

**342. Computer Integrated Manufacturing (3)** spring
Analysis and design of manufacturing systems using digital computers. Principal topics: computer-aided techniques, group technology, applications of minicomputers to manufacturing systems. Introduction to adaptive control, numerical control, and optimization strategies for discrete parts manufacturing. Term project. Prerequisite: IE 224, IE 115 or equivalent.

**343. Microprocessor Systems in IE (3)** fall
Fundamentals of microprocessors and microcomputers for industrial engineering applications. Topics include basic digital concepts, microprocessor programming interfacing, data acquisition and system development for timing, counting, decision making and control. Laboratory. Prerequisite: IE 224 and IE 115 or equivalent.

**344. Metal Machining Analysis (3)** spring
Intensive study of metal cutting emphasizing temperature and energy relationships and their effect on tool life, power requirements and surface finish. Economic balancing of metal cutting variables from application of theory. Lectures and laboratory experiments including designing and conducting an original experiment. Prerequisite: IE 115.

**345. Manufacturing Information Systems (3)**
This course examines the foundations for information systems required to support the manufacturing function throughout the product life cycle. Students will be exposed to the problems of design, implementation, and management by way of assigned readings, class

discussion of cases, and a research project. Prerequisite: IE 224 or IE 309, and 251 or equivalent.

## Graduate Programs

Programs leading to the master of science and doctor of philosophy degrees are offered by the department in the following fields: manufacturing systems, information systems, and operations research.

These programs, briefly described, are as follows:

### *M.S. in Industrial Engineering*

The minimum program for the master of science degree consists of twenty-four credit hours of approved course work and completion of a satisfactory thesis.

A master of science program is selected to meet the interests and needs of the student, and courses in other departments for which the student has the prerequisites may be integrated into the major field. Subject to proper approval, nine credit hours of 400-level courses from outside the department may be included among the courses required in the major field. As part of a purposeful major program, collateral courses may be taken in other branches of engineering, mathematics, economics, psychology, and information and computer science.

A comprehensive examination that entails a breadth of knowledge in industrial engineering is required of all candidates for this degree.

### *M.S. in Management Science*

The department and the College of Business and Economics administer an interdisciplinary program leading to a master of science degree in management science. Students are admitted and may enroll in either department for administrative purposes. The minimum program consists of thirty credit hours of approved course work.

### *M. Eng. in Industrial Engineering*

This program of study is for those students whose interests are toward design rather than research. This program will provide opportunity to gain breadth of field by required course work in all areas of study within the department. In addition, a design project is carried out under the supervision of the faculty that further emphasizes breadth of field.

A comprehensive examination that entails a breadth of knowledge in industrial engineering is required of all candidates for this degree.

### *Ph.D. in Industrial Engineering*

This program is organized to meet the individual goals and interests of industrial engineering students who plan to engage in teaching, consulting, or research activities in industrial, governmental, or educational environments.

Each doctoral student is required to demonstrate competency in several broad fields of industrial engineering related to a personal area of interest and prepare, through formal course work and independent study, for examination in the particular area of specialization by members of the faculty. A dissertation related to the field of specialization is required.

Further information about the doctor of philosophy program is contained in the Graduate School section and in a brochure available from the department.

### *Areas of Graduate Study*

The areas of graduate study and research that are emphasized in the department are as follows:

**Operations Research.** The operations research program is intended to prepare students to recognize, formulate and solve problems using combinations of analytic methods and techniques. These methods include linear programming, combinatorial optimization, queueing theory and statistics.

There are many settings in which problems solvable by operations research methods are encountered, but those which arise in the context of the manufacturing or service industries are of particular interest at Lehigh. Students can expect to encounter and study challenging and important problems at either the Masters or Ph.D. levels.

**Information Systems.** Graduate study in information systems includes course work and research in advanced systems analysis and design, advanced manufacturing databases, advanced manufacturing information systems, as well as long-range and strategic planning for information systems. Additional related courses are offered in other departments and colleges. In particular, CSEE offers courses in data communications and artificial intelligence, in both cases with strong emphasis on manufacturing. The graduate business program offers courses on the management and implementation of technology-based systems. The information systems area is supported by a laboratory containing a variety of interconnected configurations of equipment providing extensive support for both MS-DOS and UNIX operating system-based languages and tools.

**Manufacturing Systems.** Graduate study in manufacturing systems and production engineering involves course work and research in various topics related to manufacturing. These topics include computer integrated manufacturing (CIM), automation and numerical control, robotics, process control, metal machining, material handling, work systems, and production control. Additional related courses are offered in other departments in the College of Engineering and Applied Science. The manufacturing systems area is supported by several departmental laboratories, including the Manufacturing Technology Laboratory, Computer Integrated Manufacturing Laboratory, Robotics Laboratory, Microprocessor Applications Laboratory, and the Work Systems Laboratory.

A related graduate program is the interdisciplinary program in Manufacturing Systems Engineering (MSE), leading to the Master of Science degree. Details about this MSE Program are described elsewhere in this catalog.

The department offers courses during the late afternoon and early evening for the convenience of students who are employed in local industry and are taking graduate work on a part time basis.

**405. Special Topics in Industrial Engineering (3)**
An intensive study of some field of industrial engineering.

**408. (Acct 433) Management of Information Systems (3)**
Philosophies and methods for systematic planning, development, and implementation of management information systems. Concepts of information resource management, and strategic and long-range planning of information systems and services. Prerequisite: IE 224 or IE 309 or Acct 311 or equivalent.

**409. Data Dependent Systems (3)**
Theory and applications of an approach to process modeling, analysis, prediction, and control based on an ordered sequence of observed data. Single or multiple time series are used to obtain scalar or vector difference/differential equations describing a variety of physical and economic systems. Prerequisite: IE 317.

**410. Design of Experiments (3)**
Experimental procedures for sorting out important causal variables, finding optimum conditions, continuously improving processes, and trouble shooting. Applications to laboratory, pilot plant and factory. Prerequisite: Some statistical background and experimentation in prospect.

**411. Networks and Graphs (3)**
Applications of graph and network theory to the solution of problems in industrial systems. Topics include: set covering, graph coloring, location of centers, shortest paths, Hamiltonian circuits, and network flows. Prerequisite: IE 318.

**415. Manufacturing Management (3)**
Analysis of the factors entering into the development of manufacturing management philosophy; decision-making process in areas of organization, planning, operation, and control of manufacturing. Influence of the social, technical, and economic environment upon manufacturing management decisions.

**416. Dynamic Programming (3)**
The principle of optimality; one-dimensional processes, multi-

dimensional processes, LaGrange multiplier technique. Markovian decision processes; applications. Prerequisite: IE 318 or equivalent.

**417. (Mgt 445) Advanced Mathematical Programming (3)**
Theory and applications of the extensions of linear programming. Kuhn-Tucker conditions, gradient methods of optimization, simplex-based methods of nonlinear programming, integer programming, branch and bound, zero-one discrete programming, and stochastic programming. Prerequisite: IE 318 or equivalent.

**419. Sequencing and Scheduling (3)**
Study of sequencing and scheduling problems and models. Specific topics addressed are simple and parallel machine models, flow shop scheduling, analytic and simulation approaches to job shop scheduling, and extensions to resource constrained project scheduling. Prerequisites: IE 318 and IE 251 or equivalents.

**421. Nontraditional Manufacturing Processes**
Analysis of the processes, sensors, machine tools, and control systems in water jet cutting, electrochemical machining, electric discharge machining, laser and ion beam machining, and ultra high precision machining processes. Prerequisite: Consent of department chair.

**424. Robotic Systems and Applications (3)**
Detailed analysis for robotic systems in manufacturing. Topics include task planning and decomposition, motion trajectory analysis, conveyor tracking, error detection and recovery, end effector design, and systems integration. Prerequisite: IE 324 or consent of chairperson.

**428. Advanced Work Systems (3)**
A critical evaluation of methods improvement and work measurement techniques. Emphasis on design of work systems, productivity improvement, and reporting systems to control work. Work sampling, construction of standard data, mathematical models of work systems.

**429. Artificial Intelligence in Manufacturing (3)**
A variety of topics may be examined including intelligent databases, and design and development of knowledge-based expert systems. Prerequisite: IE 340 or IE 342 or equivalent.

**430. (Mgt 430) Management Science Project (3)** spring
An analysis of a management problem and design of its solution incorporating management science techniques. An individual written report is required. Recommended to be taken in the last semester of the program.

**431. Operations Research Seminar (3)**
Extensive study of selected topics in techniques and models of operations research.

**433. Manufacturing Engineering Seminar (3)**
Extensive study of selected topics in the research and development of manufacturing engineering techniques.

**437. Advanced Database Analysis and Design (3)**
Intensive treatment of design and application of modern database technology, including information modeling and logical design of databases. Particular emphasis on applications to the manufacturing environment. Prerequisite: IE 310 or equivalent.

**438. Advanced Data Communication Systems Analysis and Design (3)**
Systematic analysis and design of data communications networks through understanding of the functions and limitations of network building blocks, as well as the factors which affect design. Emphasis on local area networks as applied to the factory environment. Prerequisite: IE 341 or equivalent.

**439. Applications of Stochastic Processes (3)**
Introduction to stochastic processes, application in queueing theory and inventory theory. Prerequisites: a course in probability theory and IE 317.

**443. Automation and Production Systems (3)**
Concepts and principles of automated production lines; analysis of transfer lines; partial automation; mechanized assembly system; flexible manufacturing systems; industrial robots; line balancing; product and process design considerations.

**444. Design of Cutting Tools (3)**
A study of design parameters including tool materials, tool geometry and cutting conditions for material removal operations. Emphasis will be placed on the influence of tool selection variables, on economy of operation and conformance to product requirements.

**448. Industrial Control Systems for Manufacturing (3)**
Techniques used to control manufacturing systems: numerical control, digital control, programmable logic controllers, and sensors. Prerequisite: IE 343 or consent of department chair.

**449. Advanced Computer-Aided Manufacturing (3)**
Numerical control in manufacturing; CAD/CAM systems; computer monitoring and control of manufacturing operations; adaptive control of manufacturing operations; adaptive control and other techniques of process optimization. Manufacturing resource planning, computer-aided process planning, and shop floor control. Prerequisite: IE 342 or consent of the department chair.

**450. Manufacturing Problems (3)**
Discussion and solution of manufacturing problems involving several subfunctions, with emphasis on problem identification and definition; selection of techniques of analysis; procedures for evaluation of proposed solutions.

**460. Engineering Project (1-6)**
An intensive study of an area of industrial engineering with emphasis upon design and application. A written report is required.

**461. Readings (1-3)**
Intensive study of some area of industrial engineering which is not covered in general courses.

**490. Thesis (1-6)**

**499. Dissertation (1-15)**

# Interdisciplinary Technology Courses

See listings under Science, Technology and Society.

# International Careers

Alvin Cohen, Ph.D. (Florida), professor of economics and *director,* Foreign Careers program.

This major in the College of Arts and Science is designed to meet the needs of the student who has decided upon an international business, law, or political focus for his education. It uses elements of the traditional liberal arts and business school curricula. Among those traditional liberal arts elements are courses in economics, government, history, international relations, and language. With respect to business school offerings, there are courses in accounting, finance, and statistics. The major also represents an excellent foundation for graduate study in business, law, and the social sciences.

Each student completes the courses in the common core, takes twelve credit hours from offerings in economics, government, history, international relations, and social relations as related to an area of geographical concentration, and eighteen credit hours in a functional

option. Although not a requirement, students should study the language related to their area of specialization.

### *Major Requirements*

### *Common Core*

*(13 credit hours)*

| | |
|---|---|
| Eco 1 | Economics (4) |
| Govt 3 | Comparative Politics (3) |
| Math 21<br>Math 41 | Analytic Geometry and Calculus I (4) **or**<br>BMSS Calculus I (3) |
| Eco 145 | Statistical Methods (3) **or**<br>a comparable course in statistics |

### *Geographical Concentrations*

*(12 credit hours in one of the areas listed)*

Latin America, Europe, Russia, East Asia, the Middle East (select one)

The student selects four courses from the offerings of the relevant departments, with the consent of the director.

### *Functional Options*

*(18 credit hours in one of the options listed)*

*International Business Concentration*

| | |
|---|---|
| Acct 51 | Introduction to Financial Accounting (3) **or** |
| Acct 108 | Fundamentals of Accounting (3) |
| Eco 105 | Intermediate Microeconomic Analysis (3) |
| Eco 119 | Intermediate Macroeconomic Analysis (3) |
| Eco 229 | Money and Banking (3) |
| Eco 303 | Economic Development (3) |
| Eco 339 | International Trade (3) **or** |
| Eco/Fin 340 | International Finance (3) |

*Public Administration Concentration*

| | |
|---|---|
| Acct 51 | Introduction to Financial Accounting (3) **or** |
| Acct 108 | Fundamentals of Accounting (3) |
| IR 353 | International Institutions (3) **or** |
| IR 361 | International Law (3) |
| Eco 353 | Public Finance: Federal (3) |
| Govt 360 | Public Administration (3) |
| Govt 306 | Public Policy Process (3) **or** |
| Govt 355 | Public Personnel (3) |
| Govt 322 | Politics of Developing Nations (3) **or** |
| Eco 303 | Economic Development (3) |

# International Relations

**Professors.** Carey B. Joynt, Ph.D. (Clark), *Monroe J. Rathbone Professor, Chairperson;* Zdenek J. Slouka, Ph.D. (Columbia), *Bernard L. and Bertha F. Cohen Professor in International Relations;* Oles M. Smolansky, Ph.D. (Columbia), *University Professor;* Raymond F. Wylie, Ph.D. (London-England).
**Associate professor.** M. Rajan Menon, Ph.D. (Illinois).
**Assistant professors.** Henri J. Barkey, Ph.D. (Pennsylvania); Bruce E. Moon, Ph.D. (Ohio State).

*Curriculum.* The program in international relations serves the needs of all types of students. The student concentrating on another field and interested in taking only one or two courses in international relations will find a wide range of selections. Those seeking a more systematic exposure to international relations through a five-course minor program can design their own approach—either to survey the field or to study one of its aspects at a greater depth. For international relations majors, breadth and depth are combined; beyond a solid, common core of courses, the student selects from a range of courses within the international relations field or other disciplines. In this way, an international relations major can study a chosen region in depth (including its languages and culture) or can concentrate on a particular functional field.

To serve these diverse needs, the program of international relations employs concepts drawn from history, political science, economics, philosophy, anthropology, sociology, and psychology, and has strong links with classics, religion studies, and literature. The interdisciplinary design not only fits the tradition of a well-integrated liberal arts education; it also sets the program apart from many other undergraduate curricula which are more tightly anchored in only one or two primary disciplines. The department strongly recommends that all majors in international relations have at least a reading knowledge in one or more foreign languages.

What does the study of international relations encompass, and what is its aim? Scanning the list of course provides one part of the answer. The aim is a critical understanding of the vast forces shaping the world and penetrating all human activity—nationalism, the dynamics of war and peace, economic diversity, cultural pluralism, ideological drives, and technological change.

*Beyond curriculum.* The department encourages students to supplement their classroom work with other modes of learning, academic as well as experiential.

In close cooperation with the Center for International Studies (see page 55), the department assists students interested in internship/study abroad. In addition to summer programs in London, Geneva, Paris and Vienna, which combine internships with academic work, eligible students may be placed individually in semester- or year-long internship/study abroad programs in a number of countries in Europe and East Asia.

Every year a variety of outside speakers with diverse international experiences come to the campus and are accessible to students. The department has primary responsibility, together with the Center for International Studies, for managing the Cohen International Lecture Series; the generously endowed series brings to Lehigh community high-ranking leaders and statesmen from around the world.

At a different level, international relations students—majors and non-majors alike—participate in the student-run International Relations Club. The Club's program of activities includes sessions with outside experts, a newsletter, and the preparation for Model UN conferences held at Princeton, Harvard and other institutions. The Club also cooperates with Lehigh's own Upsilon Chapter of Sigma Iota Rho, a national honorary society in international relations. In addition, individual I.R. students are selected every year to represent the University at various outside events such as the West Point and Naval Academy student conferences.

*Beyond college.* Apart from serving the fundamental goals of liberal arts education—intellectual development and civic literacy—where does study of international relations lead?

Approximately fifty percent of international relations majors pursue further graduate study in a number of fields—political science, professional schools of international affairs, law, business, and education. Those embarking directly on career paths follow a variety of options—diplomatic service, service in federal and state agencies, careers in international organizations both public and private and including multinational corporations and international banks, or positions in firms engaged in foreign trade.

## Major in International Relations

**required preliminary courses**

| | |
|---|---|
| IR 2 | World Politics: Concepts and Principles (3) |

and one of the following:

| | |
|---|---|
| IR 1 | World Politics: Evolution of the International System (3) |
| IR 11 | European International Relations, 1815-1919 (3) |

| | |
|---|---|
| IR 12 | European International Relations Since 1919 (3) |

**required major courses**

| | |
|---|---|
| IR 325 | International Political Economy (3) or |
| IR 335 | Political economy of North-South Relations (3) |
| IR 341 | Theories of International Relations (3) |
| IR 342 | The Role of Force in International Relations (3) |
| IR 361 | International Law (3) |

**and one of the following seminars:**

| | |
|---|---|
| IR 316 | Seminar on the Soviet Union and the Third World (3) |
| IR 326 | Seminar in International Political Economy (3) |
| IR 331 | Seminar in International Relations of the Middle East (3) |
| IR 334 | Seminar on Soviet Union in World Affairs (3) |
| IR 337 | Seminar in International Politics of Technology (3) |
| IR 343 | Seminar in U.S. Defense Policy (3) |
| IR 362 | Seminar in International Law (3) |

and twelve credit hours, to be selected (with the approval of the major advisor) from courses in international relations, history, government, economics or religion studies.

**Departmental Honors**

To graduate with honors, a major in international relations must
(a) attain an average of at least 3.5 in the courses constituting the major program;
(b) demonstrate a reading competence in a foreign language; and
(c) complete a 6-credit honors thesis in the senior year.

## *Minor in International Relations*

The minor program is designed for undergraduates of any college who wish to acquire a knowledge of international relations in addition to their major. The program is flexible enough to permit students, in consultation with the minor advisor, to survey the general field of world affairs, or to focus on a specific aspect of it that may relate to their major concentration of study. Students minoring in international relations are required to take five courses (fifteen hours), of which two must be on the senior level.

## Undergraduate Courses

**1. World Politics: Evolution of the International System (3)**
Historical introduction to international politics since 1945. The modern nation-state system; nationalism and imperialism; rise of the super-powers; emergence of the Third World; outlines of a new world order.

**2. World Politics: Concepts and Principles (3)**
Introductory analysis of major theories of international relations and their application to current problems of world politics. Differing national perceptions on the nature of the international system; the exercise of political, economic and military power in the pursuit of foreign policy objectives; patterns of conflict and cooperation.

**10. Model United Nations (1)**
Research course leading to the preparation of background materials for Model UN conferences. Hours to be arranged. For pass-fail credit only. May be repeated for credit. Slouka

**11. European International Relations, 1815-1919 (3)**
Politics of the great powers; clashes of interests and international crises; development of alliances and other associations of states; wars and peace settlements; unification of Germany and Italy; influence of nationalism, the industrial revolution, and social ideologies on international relations; World War I and the peace treaties. Barkey

**12. European International Relations Since 1919 (3)**
Political and strategic structure of Europe in the 1920s; rise of Nazi Germany; politics of international crises, 1935-39; World War II and the new distribution of power in Europe; development of the cold war; European functional integration; contemporary European international problems; European relations with the United States. Barkey

**21. East Asia to 1945 (3)**
International relations of East Asia to 1945, with emphasis on 20th century: Western impact and Eastern response; origins and course of Chinese revolution; rise and fall of Japanese empire; emergence of United States and Soviet Union as Asian powers. Wylie

**22. Contemporary East Asia (3)**
International politics of East Asia since 1945, with emphasis on recent developments: origins of Cold War in East Asia; rise of China as world power; emergence of Japan as industrial giant; policies of United States and Soviet Union in Asia. Wylie

**31. Middle East in World Affairs to 1945 (3)**
Political, economic, and social forces behind the rise of modern states in the Middle East; area's role in international politics from Napoleon's invasion of Egypt to the end of World War II. Smolansky

**32. Middle East in World Affairs Since 1945 (3)**
Rise of Turkish, Iranian, and Arab nationalism; creation of Israel; decline of British and French power; growth of U.S. and Soviet influence; Middle East as the world's major oil producer. Smolansky

**41. Science, Technology, and International Relations (3)**
Interplay between technological change and the international political system. International implications of large-scale, science-based technologies: ocean exploitation system, weather modification, environmental alteration, air space and outer-space technologies, disease controls and agricultural technologies. Slouka

**51. American Foreign Policy Since 1945 (3)**
Recent and contemporary problems showing how changing international conditions affect the premises, concepts, and objects of U.S. policy. Moon

**80. Politics of Oil (3)**
Rise of large international oil companies since 1920 and their relations with the governments of producing and consuming countries, culminating in the formation of the Organization of Petroleum Exporting Countries (OPEC) and the emergence of the 'energy crisis.'

**85. Alternative World Futures (3)**
Analysis of trends in world politics, global forecasting and alternative futures: global system today; dynamics of change; methods of forecasting; political, economic and social trends; future global scenarios. Wylie

**101. Politics of European Integration (3)**
Integration process in contemporary West Europe; European communities as examples of peaceful community-building at supranational level. Institutional development of European communities and the political, economic, social dynamics of regional integration in West Europe.

**133. Diplomacy of Russia to 1945 (3)**
Expansion of the Russian Empire; Russian foreign policy under the tsarist and communist governments; interaction between domestic and foreign affairs; Soviet efforts to survive in a 'hostile capitalist environment.' Smolansky

**134. Diplomacy of Russia Since 1945 (3)**
Consolidation of gains made during and after World War II; origins of cold war; frictions within the Communist bloc (Eastern Europe and China); nuclear arms race and striving for detente. Smolansky

**161. Proseminar in World Politics (3)**
Readings on selected themes in world politics, with theme to change each semester. Emphasis on intensive study of texts and development

of reading and writing skills through oral and written reports. Prerequisite: consent of department chairperson.

## Advanced Undergraduate Courses

**302. War and World Politics (3)**
The role of war in the modern world; changing functions of war; why nations go to war; great-power wars, limited wars, civil wars, and intervention; the examples of Hitler's Germany, Japan, Korea, Vietnam, and the Arab-Israeli conflict. Prerequisites: IR 1 and 2, or consent of the chairperson. Joynt

**303. International Peace Studies (3)**
The problem of achieving a peaceful world order; the dynamics of conflict; the role of force, law, and morals. Evaluation of the proposed solutions to violent change. The nuclear era and the challenges to order posed by scarce resources and growing interdependence. Prerequisites: IR 1 and 2, or consent of the department chairperson. Joynt

**304. Multinational Corporations As International Actors (3)**
Economic, political, and social role of multinational corporations in the international system; emphasis on relations between multinational corporations and national governments. Prerequisite: IR 1 or 2.

**308. (Govt 308) Ideologies in World Affairs (3)**
Theories of ideology; nationalism and imperialism; conservatism/liberalism/socialism; Marxism/Leninism/Maoism; fascism/Nazism/militarism; Third World ideologies; the New Left, the New Right, and other recent trends. Wylie

**311. World Affairs, 1919-1945 (3)**
International relations between the world wars; structure of the state systems in 1919-22; ideals and realities of the League of Nations; challenge of Nazi Germany, Japan, Fascist Italy, and Soviet Russia; appeasement; crises of the 1930s; and World War II.

**312. World Affairs Since 1945 (3)**
International relations after World War II; its impact on the state system; cold war and development of bipolar international politics; the United Nations as an instrument for international order and security; decline of the colonial system and emergence of new states; development of Communist China and Western Europe as new power centers; and contemporary problems in international relations.

**315. The Soviet Union and the Third World (3)**
Political, economic, ideological and military aspects of Soviet policy toward the Third World since 1945. Menon

**316. Seminar on the Soviet Union and the Third World (3)**
Selected topics on the relations of the Soviet Union and Third World countries. Topic varies each year. Prerequisites: IR 315 and consent of chairperson. Menon

**318. (Govt 318) Communist Political Systems (3)**
Examination of Communist political systems outside the Soviet Union and the operations of nonruling Communist parties.

**321. China in World Affairs (3)**
Role of China in world affairs emphasizing triangular relationship involving China, United States, and Soviet Union. Other topics include: Maoist ideology and domestic politics; making of foreign policy; relations with Japan and Europe; policies toward the Third World; current and future problems. Wylie

**322. (Govt 322) Politics of Developing Nations (3)**
Theories of political development in non-Western areas: modernization and nation building. Field studies and methods; contributions of related disciplines such as sociology and psychology.

**323. Japan in World Affairs (3)**
Emergence of Japan as key actor in post-1945 world politics. Changes in the international system as well as the internal dynamics of Japan are examined for their contribution to Japan's rise to power. Wylie

**325. (Govt 325) International Political Economy (3)**
Development of forms of political management of the world economy since World War II, with emphasis on control of interdependence among the industrialized countries, achievement of equity in relations between developed and developing countries, and reintegration of the centrally planned economies into the international economy. Prerequisites: IR 1 and 2, or consent of chairperson. Moon

**326. Seminar in International Political Economy (3)**
Analysis of selected issues in contemporary international economic relations, with emphasis on O.E.C.D. countries. Topic varies each year. Prerequisites: IR 325 and consent of chairperson. Moon

**331. Seminar in International Relations of the Middle East (3)**
Importance of the region in contemporary world politics; strategic location and natural resources as factors affecting interests of the great powers. Interplay of international, regional and internal forces. Prerequisites: IR 31 or IR 32 and consent of chairperson. Smolansky

**334. Seminar on Soviet Union in World Affairs (3)**
Objectives, strategy and tactics of Soviet diplomacy: Russia's status as a superpower. Prerequisites: IR 134 and consent of chairperson. Smolansky

**335. Political Economy of North-South Relations (3)**
Political economy of relations between developing and developed countries. Political context of foreign aid, trade policy, multinational corporations, and negotiations over the New International Economic Order. Menon, Moon

**337. Seminar in International Politics of Technology (3)**
Research course in selected areas of world politics affected by technological change excluding weapon technologies. Prerequisites: IR 1 or 2, and IR 41 or 335, or consent of chairperson. Slouka

**341. Theories of International Relations (3)**
Contemporary theories and basic concepts of world politics; application to historic and current issues of international relations. Prerequisites: IR 1 and 2, or consent of the chairperson. Joynt

**342. The Role of Force in International Relations (3)**
Role of force in international politics: deterrence, limited war, problems of arms control and disarmament; crisis diplomacy. Prerequisites: IR 1 and 2, or consent of the chairperson. Joynt

**343. Seminar in U.S. Defense Policy (3)**
Analysis of U.S. defense policies. Prerequisites: IR 342 and consent of chairperson. Joynt

**353. International Institutions (3)**
Role of international institutions in world politics. Interplay and functions of intergovernmental and nongovernmental organizations. Decision making, authority and sources of influence. Political, economic, social and scientific-technological organizations of global and regional scope. Slouka

**354. Atlantic Community (3)**
Political, cultural, and strategic influences affecting relationship between Western Europe, United States, and Canada; the North Atlantic Treaty Organization; strains in the community, and prospects.

**355. Problems in United States Foreign Policy (3)**
Analysis of selected major issues in U.S. foreign policy. Prerequisite: IR 51 or consent of chairperson. Joynt

**361. International Law (3)**
Function of law in international relations, Foundation and structure of international law. Sources of international legal rights and obligations. International law-making and settlement of disputes. Prerequisites: IR 1 and 2, or consent of chairperson. Slouka

**362. Seminar in International Law (3)**
Case studies in the dynamics of international regulatory processes. Political, socio-economic, and cultural foundations of the international legal system. Prerequisites: IR 361 and consent of chairperson. May be repeated for credit. Slouka

**371. Reading in International Relations (3)**
Directed course of reading intended for students with special competence or interest in fields of international relations not fully covered by regular course offerings. May be repeated for credit. Prerequisite: consent of chairperson.

**372. Reading in International Relations (3)**
Continuation of IR 371. May be repeated for credit. Prerequisite: consent of chairperson.

**375. Internship in International Relations (1-3)**
Internship in public or private agency. May be repeated for credit. Prerequisite: consent of chairperson.

**381. Special Topics (3)**
Intensive study of some aspects of international politics not covered in another course. Prerequisite: consent of chairperson.

**382. Special Topics (3)**
Continuation of IR 381. Prerequisite: consent of chairperson.

# Journalism

**Professor.** Sharon M. Friedman, M.A. (Penn State), *chairperson and director of science writing program.*
**Associate professors.** Carole M. Gorney, M.S.J., A.P.R. (Northwestern); Walter W. Trimble, M.A. (Ohio State).
**Assistant professors.** Dina Wills, Ph.D. (Oregon); Frankie Hutton, M.A. (South Carolina).
**Adjunct professors:** Kenneth Friedman, Ph.D. (Penn State); Glenn Kranzley, B.A. (Penn State); William White, M.A. (Ohio State); Perry Zirkel, J.D., Ph.D. (Connecticut).

The department of journalism offers major and minor programs in print journalism and science writing as well as a minor program in public relations and speech.

The profession of journalism deals with the truthful communication and explanation of facts. It is the purpose of the program in journalism to bring its majors to a point at which they can gather significant information, organize it quickly and communicate it clearly, accurately and objectively, and to bring them to an understanding of the legitimate role of the mass media in society.

The first of these objectives is attained by extensive, professionally oriented practice in the reporting, writing and editing of the news. Emphasis is placed on precision and clarity of expression and sophistication of style.

The second objective is attained by study of the rights and responsibilities of the mass media under the U.S. Constitution and by a senior seminar course in which problems facing the media and the relationship between the media and society are examined.

In the basic journalism program, students take courses in news and feature writing, editing, law and ethics, reporting, and a seminar in mass media. In addition, many students pursue a concentration in at least one of the following areas: American studies, economics, government, history, international relations, languages, literature, philosophy, religion studies, various scientific disciplines, social relations and urban studies. Some journalism students elect to pursue a double major. Others choose a minor or a concentration in one of these fields.

A second major program available to journalism students is science writing. Those selecting this major will learn to write, in terms understandable to the general public, about pure and applied scientific research, technology and engineering, medicine and the environment. A minor in science writing is available for those who wish to major in science or engineering and to become skilled in science communication techniques.

Students interested in environmental writing may wish to pursue a bachelor of science degree in environmental sciences and resource management (ESRM), with a concentration in environmental science writing. This option is offered through the ESRM interdisciplinary program in cooperation with the department of journalism. Students are required to take a core sequence of science courses and eighteen credit hours in the science writing program. For details, refer to the ESRM program description on page 139.

All science and environmental writing students may enroll in the science writing field research program, which offers a unique opportunity for practical experience in scientific research and science writing. They also may gain experience by serving on the staff of *Science Scope*, a student-written publication devoted to research at Lehigh.

A public relations minor is available to students interested in a career in such areas as nonprofit, governmental and corporate public relations. The courses offered cover theory, skills and practical application of public relations.

A minor in speech is offered to students interested in developing oral communications skills while studying principles of effective speaking, media analysis, interviewing, persuasion and group process.

Although most journalism graduates choose some phase of written communication as a career—newspapers, wire services, magazines, public relations, advertising, technical writing—others have used their background in journalism as a basis for the study and practice of law, graduate study in a variety of disciplines, government service, teaching and business management.

Those concentrating in science writing can expect to pursue careers in science journalism; in public information or public relations for scientific societies, government agencies, universities or hospitals; in technical writing; and in other areas, such as management, administration and teaching, in which science communication skills are highly desirable. The program also prepares students for graduate study in science writing, journalism and other disciplines.

Students who complete the public relations minor will be prepared for both entry-level positions and for management responsibilities that are likely to occur later in the students' careers. Studies in writing, communication and media give minors a grasp of the basics essential for the first job in public relations. An emphasis on planning, programming and management techniques provides the background needed to respond to advancement opportunities in the field.

The speech minor guides the student to a better understanding of how people share meaning through persuasive use of rhetoric, logic and symbols in public, one-to-one, and small group communication. It is useful to students interested in law, business, philosophy, government, marketing, teaching, telecommunication, or any other career where it is necessary to communicate information successfully to others.

## *Basic Journalism Major*

**required preliminary courses**

| | |
|---|---|
| Jour 1 | Brown & White (1) |
| Jour 11 | News Writing (4) |

**required major courses**

| | |
|---|---|
| Jour 2-3 | Brown & White (2)* |
| Jour 12 | Feature Writing (3) |
| Govt 77 | Urban Politics (3) |
| Jour 113 | Editing (3) |
| Jour 122 | Media Ethics and Law (3) |
| Jour 161 | Internship (3) |
| Jour 214 | Reporting of Public Affairs (4) |
| Jour 315 | Advanced Reporting (3) |
| Jour 320 | Journalism Proseminar (3) |

**plus two of the following:**

| | |
|---|---|
| Jour 127 | Public Relations Theory (3) |
| Jour 141 | Photojournalism (3) |
| Jour 125 | Environment, the Public and the Mass Media (3) |
| Jour 215 | Advanced Editing (3) |
| Jour 220 | Reporting on Business and Economics (3) |
| Jour 221 | International Reporting (3) |
| Spch 331 | Business and Professional Speaking (3) |

Thirty-eight credits are required.

*Note: A minimum of three semesters is required on *The Brown and White*. The course involves work on the student newspaper. One of the three required semesters must be taken during the student's junior year, and one must be taken during the senior year.

**Dual major and recommended electives.** Journalism majors are encouraged to declare dual majors in journalism and another field, such as one of those discussed under concentrations above. In-depth knowledge of a specialty area is considered an asset to a journalism career. Those not desiring to declare a dual major should consider either declaring a minor in one of these fields or concentrating their elective courses in one or two of these areas. Dual majors, minors and concentration areas should be chosen in consultation with the major adviser.

## *Journalism/Science Writing Major*

**required preliminary courses**

| | |
|---|---|
| Jour 1 | Brown & White (1) |
| Jour 11 | News Writing (4) **or** |
| Jour 123 | Basic Science and Technical Writing (3) |

**required major courses**

| | |
|---|---|
| Jour 2-3 | Brown & White (2)** |
| Govt 77 | Urban Politics (3) |
| Jour 113 | Editing (3) |
| Jour 122 | Media Ethics and Law (3) |
| Jour 124 | Politics of Science (3) |
| Jour 125 | Environment, the Public and the Mass Media (3) |
| Jour 128 | Writing for Public Relations (3) |
| Jour 161 | Internship (3) |
| Jour 214 | Reporting of Public Affairs (4) |
| Jour 313 | Special Topics in Science Writing (3) |

Thirty-four journalism credits are required.

**Note: A minimum of three semesters is required on *The Brown and White*. The course involves work on the student newspaper. One of the three required semesters must be taken during the student's junior year, and one must be taken during the senior year.

**Required science courses.** A minimum of twenty-four credits in the physical, biological, environmental or social sciences or engineering is required. These hours can be concentrated in any one area or distributed among all five areas, although an area concentration is recommended. Dual majors in journalism/science writing and a science are encouraged. Science courses should be chosen in consultation with the major adviser.

**Science writing field research program.** Available to science or environmental writing students at the junior or senior level, this program provides practical experience in scientific research and science writing for students who work on and write about research projects directed by university scientists and engineers.

Another segment of the program allows students to attend major scientific meetings as fully accredited science reporters. Students observe professional science writers in action and write their own stories about the scientific sessions and press conferences held at the meetings.

## *Journalism Minor*

Students who wish to declare a minor program in journalism must be majors in another discipline and take the following:

| | |
|---|---|
| Jour 1-2 | Brown & White (2) |
| Jour 11 | News Writing (4) |
| Jour 12 | Feature Writing (3) |
| Jour 113 | Editing (3) |
| Jour 315 | Advanced Reporting (3) |

Fifteen credits are required.

## *Science Writing Minor*

Students desiring to minor in science writing must be majors in another discipline, preferably a science or engineering. The following courses are required:

| | |
|---|---|
| Jour 1-2 | Brown & White (2) |
| Jour 11 | News Writing (4) **or** |
| Jour 123 | Basic Science and Technical Writing (3) |
| Jour 124 | Politics of Science (3) |
| Jour 125 | Environment, the Public and the Mass Media (3) |
| Jour 128 | Writing for Public Relations (3) |
| Jour 312 | Advanced Science Writing (3) **or** |
| Jour 313 | Special Topics in Science Writing (3) |

Seventeen or eighteen credits are required.

## *Public Relations Minor*

Students minoring in public relations must be majors in another discipline and take the following courses:

| | |
|---|---|
| Jour 11 | News Writing (4) **or** |
| Jour 123 | Basic Science and Technical Writing (3) |
| Jour 127 | Theory of Public Relations (3) |
| Jour 128 | Writing for Public Relations (3) |
| Jour 229 | Public Relations Case Studies (3) |
| Jour 161 | Internship (3) **or** |
| Jour 306 | Applied Public Relations (3) |

**plus one of the following:**

| | |
|---|---|
| Jour 12 | Feature Writing (3) |
| Jour 215 | Advanced Editing (3) |
| Jour 220 | Reporting on Business and Economics (3) |
| Spch 331 | Business and Professional Speaking (3) |

Eighteen or nineteen credits are required.

## *Speech Minor*

Students who wish to minor in speech should choose courses from among the following:

| | |
|---|---|
| Spch 60 | Fundamentals of Speech Communication (3) |
| Spch 130 | Public Speaking (3) |
| Spch 331 | Business and Professional Speaking (3) |
| SPsy 121 | Social Psychology of Small Groups (3) |
| SPsy 135 | Human Communication (3) |

For majors in the College of Business and Economics:

| | |
|---|---|
| Mgt 270 | Organization Theory and Behavior (3) |
| Mgt 307 | Business Communication Skills (3) |

Selected courses in journalism could count toward this minor. Check with the speech minor adviser for specific course suggestions. Fifteen credits are required.

## *Computer Writing Laboratories*

Students taking journalism courses will receive extensive experience with mass media computer applications. All writing and editing labs are conducted in one of the department's two computer facilities. One uses a newspaper production word processing and editing system of sixteen terminals, which are connected to a typesetter and laser printers. The other lab features seventeen MS-DOS microcomputers, which are connected to both the newspaper lab network and the university-wide network and can be used to teach desk-top publishing.

# Journalism Courses

**Media Internships**
All majors in journalism and journalism/science writing are

required to take an internship to acquire professional experience with area newspapers or magazines, or in an institutional, public relations or advertising setting.

**1. Brown and White (1)** every semester
Enrollment constitutes membership on the staff of the semi-weekly undergraduate newspaper. Newspaper staff members are selected based on their interests and skills. Students who preregister for this course are told at the beginning of the semester whether they have been selected for the staff. First- and second-semester freshmen are given priority. Prerequisite: Freshman or sophomore standing; juniors only with consent of department chairperson.

**2-10. Brown and White (1-2)** every semester
Enrollment constitutes membership on the staff of the semi-weekly undergraduate newspaper. Newspaper staff members are selected based on their interests and skills. Students who preregister for this course are told at the beginning of the semester whether they have been selected for the staff. Prerequisite: Jour 11 or Jour 123 or consent of the department chairperson.

**11. News Writing (4)** every semester
Definition, determinants, and components of news; news story structure and style; sources; interviewing; practice in gathering and writing news.

**12. Feature Writing (3)** every semester
Defining and developing feature stories: human interest, historical, color, personality and news issues; specialized interviewing and writing techniques. Prerequisite: Jour 11 or Jour 123. Trimble, Gorney

**113. Editing (3)** every semester
Study of and practice in newspaper desk work; headline writing, makeup, and typography; selecting, editing and rewriting news and feature copy; use of reference works and newspaper libraries. Prerequisite: Jour 11 or Jour 123. Trimble

**122. Media Ethics and Law (3)** spring
Law of and defenses in libel; privacy; contempt; copyright; obscenity. Ethical issues related to newsgathering and publication. Prerequisite: Jour 11, Jour 123 or Law 11. Zirkel

**123. Basic Science and Technical Writing (3)** fall
Writing about science and technology subjects for audiences ranging from lay persons to scientists and engineers. Includes instruction in news and feature writing plus interviewing for lay audiences, with emphasis on organization and clear writing techniques. As course progresses, material becomes more technical in nature, concentrating on how to write effective technical reports, progress reports, letters, memos, and scientific journal articles. Prerequisite: six hours of science or consent of department chairperson. Friedman

**124. (STS 124) Politics of Science (3)** spring
Organization of the U.S. scientific community and how it interacts with government, the mass media and the public. Friedman

**125. Environment, the Public and the Mass Media (3)** fall
Public perceptions of environmental problems and of roles played by business, government, the mass media and environmental groups. Analysis of techniques of persuasion, with student investigations of regional environmental problems. Friedman

**127. Public Relations Theory (3)** fall
Emphasis on management function of public relations, including research, planning, programming, communications and evaluation. Study of communication and persuasion theory, public opinion, crisis management and ethics. Student teams apply theory to practical organizational problems. Gorney

**128. Writing for Public Relations (3)** spring
Study of the preparation and writing of publicity for print and broadcast media, publications (newsletters, pamphlets, annual reports), speeches and audio-visual presentations, especially for non-profit and environmental groups. Prerequisite: Jour 11 or 123 or 311 or consent of department chairperson. Friedman, Gorney

**135. (Spsy 135) Human Communication (3)**
Processes and functions of human communication in relationships and groups. Rosenwein

**141. Photojournalism (3)**
Ethics and history of photojournalism; practice in techniques of distinguished photojournalists, camera use and darkroom. Students must provide own 35mm. camera. Enrollment limited. Trimble, Gorney

**161. Internship (1-6)** every semester
Professionally supervised work on commercial newspapers, magazines, radio and television stations, or with public relations and advertising organizations. Some internships involve science writing. May be repeated for a maximum of six credits. Prerequisite: Declared major or minor in journalism, science writing, public relations or speech. Friedman, Trimble

**214. Reporting of Public Affairs (4)** spring
Reporting and writing news of government on the local, county, state and federal levels; civil and criminal courts; labor, environment, housing and community planning news. Prerequisites: Jour 11 or 123 and Govt 77. Trimble

**215. Advanced Editing (3)**
Study of the techniques of newspaper, magazine and pamphlet design: typography and other visual elements, preparation of copy and artwork, use of microcomputer-based desktop publishing. Prerequisite: Jour 113 or permission of the department chairperson. Trimble

**220. Reporting on Business and Economics (3)**
The principles behind the economy, the markets and companies and how to report on them; the role of business reporting in the media; the use of computer technology in business reporting. Prerequisite: Jour 11 or Jour 123 and Eco 1.

**221. International Reporting (3)**
The role of the media in the Third World and communist countries and how that differs from the media's role in the West; problems reporters face in covering international news. Prerequisite: Jour 11 or Jour 123.

**229. Public Relations Case Studies (3)** fall
Analysis of public relations programs in business, industry, government, and non-profit organizations. Emphasis on specific problems and methods used. Prerequisite: Jour 127 or consent of department chairperson. Gorney

**231. Science Writing Practicum (1-3)**
On-site experience as accredited science reporter at major scientific meetings, or writing and research in university laboratories as part of Science Writing Field Research Program. May be repeated for a maximum of eight credits. Prerequisites: Jour 11 or Jour 123 or Jour 311, junior standing, and consent of the department chairperson. Friedman

**233. Public Relations Practicum (1-3)**
Practical experience in public relations competitive programs sponsored by professional and academic societies. May be repeated for a maximum of eight credits. Prerequisites: Jour 127, junior standing and consent of department chairperson.

**306. Applied Public Relations (3)** spring
Application of public relations theories and practices to hypothetical and real problems in business, government and non-profit organizations. Prerequisites: Jour 127 and Jour 128 or consent of department chairman. Gorney

**311. Science and Technical Writing (3)** fall
Study of and practice in writing about science and technology for general print, electronic media and specialized science publications. Includes news and feature articles, report writing and analysis of factors that influence science communication to the public. Emphasis on writing and organizational skills and translation of scientific materials into lay language. Should be taken by upperclass and

graduate students instead of Jour 123. Prerequisite: six hours of science or consent of department chairperson. Friedman

**312. Advanced Science Writing (3)**
Further practice, on individual basis, in science writing techniques. Prerequisite: Jour 123 or 311. Friedman

**313. Special Topics in Science Writing (3)** fall
Extensive analyses of media reporting on controversial scientific and technological topics. Use of public opinion polling, computer analysis, and media databases emphasized for interpretive articles. Prerequisite: Jour 11 or Jour 123 or Jour 311, or consent of the department chairperson. Friedman

**315. Advanced Reporting (3)**
Techniques for reporting on social, political and economic trends in communities; intensive practice in investigative reporting. Prerequisite: Jour 214 or permission of the department chairperson. Trimble

**320. Journalism Proseminar (3)** spring
Survey of the press in its relation to public affairs. Extensive research and reports. Prerequisite: consent of the department chairperson. Trimble and staff

### Speech Courses

**Spch 60. Fundamentals of Speech Communication (3)**
The basic principles of communication: the informative speech, small group communication process, principles of persuasion, effects of mass communication. Two speeches, group project. Wills

**Spch 130. Public Speaking (3)**
Practice in planning and presenting informative and persuasive speeches. Five or six speeches per student. Wills

**Spch 331. Business and Professional Speaking (3)**
The principles of oral communication as applied to business and professional situations. Business presentations, small group interaction and presentation, interpersonal communication in the business setting. Prerequisite: junior or senior standing. Wills

# Languages

Courses are listed alphabetically under Modern Foreign Languages.

# Latin American Studies

See listings under Modern Foreign Languages. See also Foreign Careers, where an undergraduate may concentrate on Latin America as a geographical concentration.

# Latin American Studies

See listings under Modern Foreign Languages. See also International Careers, where an undergraduate may choose Latin America as a geographical concentration.

# Law and Business

**Professors.** Brian G. Brockway, J.D., LL.M. (Georgetown), *Distinguished Professor of Law;* Perry A. Zirkel, J.D., LL.M. (Yale), Ph.D. (Connecticut), *University Professor of Education and Law.*
**Assistant Professors.** Ifeanyi Achebe, J.D. (Howard University), LL.M. (New York University); George Nation III, J.D. (Villanova).

The Department of Law and Business is responsible for the law program in the College of Business and Economics and participates in the Law and Legal Institutions program. Members of the Department provide pre-law advice for students in the College. A major program of studies is not offered.

### Undergraduate Courses

**11. Introduction to Law (3)**
A study of the nature and function of law and the legal system, the study of legal reasoning through the use of the case method. Required first course in the Law and Legal Institutions minor program. Open only to freshmen and sophomores except with the consent of the coordinator of the program.

**201. Legal Environment of Business (3)** Every semester.
The study of the legal relationships of business and government, business and society and the individual and society. The case method is used to develop analytical skills. Introduction to contract law and the law of sales underlying the free market system. Prerequisite: Eco 1.

**202. Business Law (3)** every semester
The law of sales, contracts, agency, business organizations, secured transaction, property and negotiable instruments. Prerequisite: Law 201.

**221. (Phil 221) Sex-Discrimination and the Law (3)**
A critical study of the law of sex discrimination in areas of constitutional and labor law. A case approach that places emphasis on the rights of employees and the obligations of employers. Topics include equal protection, equal employment opportunity, and affirmative action. Lindgren

**371. Directed Readings (1-3)**
Readings in various fields of law, designed for students who have a special interest in afield of law.

**372. Special Topics (3)**
Special problems and issues in commercial law.

### Graduate Courses

**404. Legal Environment of Management (3)**
The effect of public and private law on business decisions. The legal relationship of business and society and business and government, especially the government regulation of business. Introduction to contract law underlying the free market system.

**437. Federal Taxation and Business Decisions (3)**
Impact of federal taxation on the structure and timing of business decisions. Problem-solving methods and research techniques from a managerial perspective. Not available to students with two or more courses in taxation. Prerequisite: a basic course in accounting.

# Management

**Professors.** Richard W. Barsness, Ph.D. (Minnesota), *dean of the College of Business and Economics;* Alden S. Bean, Ph.D. (Northwestern), *Kenan Professor of Management and Technology;* John W. Bonge, Ph.D. (Northwestern); James B. Hobbs, D.B.A. (Indiana), *Frank L. Magee Professor of Business Administration;* Benjamin Litt, Ph.D. (N.Y.U.); Theodore W. Schlie, Ph.D. (Northwestern).
**Associate professors.** Michael G. Kolchin, D.B.A. (Indiana), *Sue*

*and Eugene Mercy, Jr. Professor of Business and Economics;* John E. Stevens, Ph.D. (Cincinnati).
**Assistant professors.** Alfred J. Bird, Ph.D (Houston); Peter P. Poole, Ph.D. (Penn State); Susan A. Sherer, Ph.D. (Pennsylvania).

## *Management Program and Courses*

Each undergraduate management major will select either the *Specialization* (15 hours) or *Interfunctional* (18 hours) track shown below:

### *Specialization (15 hours)*

**required courses:**

| | |
|---|---|
| Mgt 302 | Quantitative Models-Conceptual (3) |
| Mgt 321 | Organizational Behavior Workshop (3) |

*Plus at least one of the following:

| | |
|---|---|
| Mgt 309 | Industrial Purchasing and Materials Management (3) |
| Mgt 311 | LUMAC Management Assistance Counseling (3) |
| Mgt 331 | Industrial Relations and Public Policy (3) |
| Mgt 333 | Personnel Management (3) |

Up to two of the following:

| | |
|---|---|
| Acct 324 | Cost Accounting (3) |
| Eco 333 | Managerial Economics (3) |
| Eco 335 | Labor Economics (3) |
| Eco 352 | Advanced Statistical Methods (3) |
| Eco 357 | Econometrics (3) |
| Fin 328 | Corporate Financial Policy (3) |
| Mkt 319 | New Product Planning (3) |
| Mkt 321 | Marketing in the Industrial Environment (3) |
| IE 309 | Introduction to Information Systems (3) |
| IE 334 | Organizational Planning and Control (3) |
| IE 332 | Product Quality (3) |

*Courses other than Mgt 302 and Mgt 321 will be selected in consultation with the faculty advisor to comprise one of the following specialization options: entrepreneurship, human resources management, materials management, and operations management.

### *Interfunctional (18 hours)*

**required courses:**

| | |
|---|---|
| Mgt 302 | Quantitative Models-Conceptual (3) |
| Mgt 321 | Organizational Behavior Workshop (3) |
| Acct 324 | Cost Accounting (3) |
| Fin 328 | Corporate Financial Policy (3) |
| Mkt 319 | New Product Planning (3) **or** |
| Mkt 321 | Marketing in the Industrial Environment (3) |

Plus one of the following:

| | |
|---|---|
| IE 309 | Introduction to Information Systems (3) |
| IE 334 | Organizational Planning and Control (3) |
| IE 332 | Product Quality (3) |

## Undergraduate Courses

**Mgt 1. Introduction to Business Computing (3)** fall and spring
A one-semester survey of computer technology and software applications in business and economics. Topics include introduction to computer architecture and logic, operating systems, spreadsheets, and data base management systems. Students will develop a working knowledge of microcomputers, mainframes and the campus-wide network. Limited to freshmen only. (Mgt. 1 will be a prerequisite for many courses in the College of Business and Economics.)

**Mgt 101. (ECO 101) Introduction to Quantitative Methods (3)**
Mathematical concepts within a business and economics framework: linear algebra, partial derivatives, constrained optimization, and integral calculus. Meets mathematics prerequisite for entering students in the master of business administration program. Not available for credit to undergraduates in the College of Business and Economics.

**Mgt 269. Management of Operations in Organizations (3)** fall-spring
Design, operation and control of activities necessary to generate goods or services of profit and nonprofit organizations. Basic concepts and quantitative modes used in operations. Eco 145, Math 44. Sherer

**Mgt 270. Organization Theory and Behavior (3)** fall-spring
Formal organizations as ongoing systems. Emphasis is placed on the introduction of theory applicable to the management of human behavior in work environments. Issues at the individual, group, and organizational levels of analysis are addressed. Topics covered include motivation, stress, career processes, leadership, conflict management, decision making, work politics, organizational design, and organizational development. Poole

**Mgt 301. Business Management Policies (3)** fall-spring
Case study of business problems and the formulation of policies, strategies and tactics to resolve those problems from the viewpoint of general management. Long-range goal attainment, policy formulation, and administrative implementation for specific functional areas and the total firm. Prerequisite: senior standing in the College of Business and Economics, and completion of the college core.

**Mgt 302. Quantitative Models-Conceptual (3)**
Quantitative methodologies and their use in business, economics and related areas. Classical optimization techniques, mathematical programming, linear programming, decision theory, game theory, simulation and network models. Prerequisites: Eco 105, Acct 111 and Mgt 269. Bird

**Mgt 306. Entrepreneurship and Business Policy (3)** spring
Case study of problems in creating new ventures or managing family-owned businesses. Integrates knowledge acquired in other courses and stresses development of strategic and administrative policies for particular functions and the company as a whole. Prerequisites: senior standing, completion of College of Business and Economics core, and Mgt 311, as well as approval of the department chairperson. Students may not receive credit for both Mgt 306 and Mgt 301. Bonge

**Mgt 307. Business Communication Skills (3)**
Written and spoken communication through letters, memos, reports, and oral presentations. Formal and informal communication networks, and communication processes. Prerequisite: consent of instructor.

**Mgt 309. Industrial Purchasing and Materials Management (3)** spring
Negotiating, purchasing, receiving, storing, inventory control, value analysis, procurement information systems, and specialized problems in institutional and government procurement. Lectures and cases. Prerequisite: Mgt 269 or equivalent. Kolchin

**Mgt 311. LUMAC Management Assistance Counseling (3)** fall-spring
A field studies course providing management assistance to small businesses in the Lehigh Valley. Students work in small groups under faculty supervision on a direct basis with owners. Problem solving and experience in applying marketing, accounting, finance, and/or management concepts to business. Prerequisites: junior standing in the College of business and Economics. Bonge, Stevens

**Mgt 321. Organizational Behavior Workshop (3)**
A workshop course examining individual behavior, interpersonal transactions and behavioral processes in small work groups through motivational analysis, role-playing nonverbal interactions, problem solving and group simulations. Prerequisites: Mgt 270 and permission of the department chairperson. Poole

**Mgt 331. Industrial Relations and Public Policy (3)**
An examination of the evolution and current status of U.S. public

policy toward the organization and recognition of labor unions, collective bargaining, labor contract administration, and arbitration of disputes as expressed in federal statutes, court decisions, and National Labor Relations Board rulings. Stevens

**Mgt 333. Personnel Management (3)** fall
Analysis and resolution of personnel problems in organizations. Human resource planning, recruitment, selection, orientation, training, appraisal, compensation, and development. Lectures and cases. Prerequisite: Mgt 270. Kolchin, Stevens

**Mgt 371. Directed Readings (1-3)**
Readings in various fields of management designed for the student who has a special interest in some field of management not covered by the regularly scheduled courses. Prerequisite: consent of the department chairperson. May be repeated.

**Mgt 372. Special Topics (1-3)**
Special problems and issues in management for which no regularly scheduled coursework exists. When offered as group study, coverage varies according to interests of instructor and students. Prerequisite: consent of the department chairperson. May be repeated.

## For Graduate Students

**Mgt 401. Quantitative Methods in Business and Economics (3)**
Management science methods and applications. Mathematical programming, simulation, decision theory, game theory, network models and statistics. Prerequisite: Eco 401 or equivalent. Bird

**Mgt 409. Purchasing and Materials Management (3)**
Overview of the purchasing and materials functions in organizations: Negotiation, buying, receiving, storing, inventory control, value analysis, legal aspects, and specialized problems in institutional and government procurement. Combination of lectures and case analyses. Kolchin

**Mgt 413. Organizational Behavior and Management (3)**
Interpersonal and group behavior in organizations. Issues of organization work and perception, motivation, communications, conflict, leadership, and organization structure. Kolchin, Litt, Poole

**Mgt 423. Operations Management (3)**
Capacity planning and aggregate scheduling, inventory theory including MRP and JIT, production scheduling, standards and quality control, and project management. Prerequisite: Mgt 401 (or equivalent). Sherer, Stevens

**Mgt 425. Human Resource Management (3)**
A survey of personnel management activities in organizations. Topics include human resource planning, recruitment, selection, equal employment opportunity, evaluation, compensation, career planning, safety and health. Kolchin, Stevens

**Mgt 429. Managerial Policy and Decision-Making (3)** fall-spring
Integration of theory and analytic techniques through intensive investigation of complex organizational, strategic and financial problems in industrial and nonbusiness entities. Case studies. Prerequisite: graduate-level exposure to accounting, economics, finance, management and marketing. An MBA candidate should take the course near the end of the MBA program. Hobbs

**Mgt 430. (IE 430) Management Science Project (3)**
As an individual or as a member of a small group, analysis of a management problem and the design of its solution is made incorporating management science techniques. An individual written report is required. Recommended that it be taken in the last semester of the M.S. in management science program.

**Mgt 431. Organizational Design and Change (3)** fall
Variables relevant to determining the design of structures and processes of organizations; techniques pertinent to organizational adaptation to changed environments, technologies and social factors. Prerequisite: Mgt 413. Bonge

**Mgt 433. Corporate Enterprise: Concepts and Issues (3)**
Examines issues relevant to modern corporate enterprises: managing technological innovation; role of public policy; managerial values-ethics and human resources. Barness, Bean, Litt

**Mgt 435. Organizational Decision Processes (3)**
Examines individual responsibility and information handling styles in managerial decision-making processes in formal organizations. Negotiated decision-making, joint problem solving, and values based decision-making processes. Prerequisite: Mgt 413. Litt

**Mgt 445. (IE 417) Advanced Mathematical Programming (3)**
Theory and applications of the extensions of linear programming. Tucker-Kuhn conditions, gradient methods of optimization, simplex-based methods of nonlinear programming, integer programming, branch and bound, zero-one discrete programming and stochastic programming. Prerequisite: a course in linear programming.

**Mgt 447. Analytical Methods in Management (3)**
Application of management science methods to industrial and commercial problems. Scientific method, decision theory, linear programming, inventory control, regression analysis, forecasting, simulation, and related areas are examined in the context of accounting, finance, marketing, and manufacturing.

**Mgt 455. Managerial Communication Skills (3)**
Organization, style, and strategy of language to inform, direct, and persuade. Application of writing, reading, speaking, and listening skills to managerial problems. Case studies.

**Mgt 457. Technology Management Seminar (3)**
Review of current literature on technology management with emphasis on relation among business strategy, competitive conditions, management practice and the technological innovation process. Case studies and outside speakers. Critical analysis of research and application to technology management problems. Bean

**Mgt 471. Directed Readings (1-3)**
Graduate readings in management not covered in regularly scheduled coursework. Prerequisite: consent of the department chairperson. May be repeated.

**Mgt 472. Special Topics (1-3)**
Special problems and issues in management for which no regularly scheduled graduate coursework exists. When offered as group study, coverage will vary according to the interests of instructor and students. Prerequisite: consent of the department chairperson. May be repeated.

# Manufacturing Systems Engineering

**Program director (acting).** Keith M. Gardiner, Ph.D. (Manchester, England), *visiting professor of manufacturing systems engineering.*
**Program faculty.** Mikell P. Groover, Ph.D. (Lehigh), *MSE associate director, professor of industrial engineering;* Benjaminn Litt, Ph.D. (N.Y.U.), *professor of management;* Roger N. Nagel, Ph.D. (Maryland), *Harvey Wagner Professor of manufacturing systems engineering;* John B. Ochs, Ph.D. (Penn State), *associate professor of mechanical engineering and mechanics;* Nicholas G. Odrey, Ph.D. (Penn State), *associate professor of industrial engineering;* N. Duke Perreira, Ph.D. (California, Los Angeles), *associate professor of mechanical engineering and manufacturing systems engineering;* Richard Roberts, Ph.D. (Lehigh), *professor of mechanical engineering and mechanics;* Bruce M. Smackey, Ph.D. (Rensselaer), *associate professor of management and marketing;* Emory W. Zimmers, Jr., Ph.D. (Lehigh), *professor of industrial engineering;* Tulga Ozsoy, Ph.D. (Tech. Univ. of Istanbul), *assistant professor of mechanical engineering and mechanics;* George R.

Wilson, Ph.D. (Penn State), *associate professor of industrial engineering.*

The graduate curriculum in MSE is designed to develop engineers who can design, install, operate and change manufacturing systems which involve people, machines, new materials, information systems and appropriate technology. It is a program which integrates systems perspectives with interdisciplinary education and training.

This curriculum leads to a Master of Science degree in Manufacturing Systems Engineering and is designed as a one-year full-time program starting each January. It requires a minimum of 30 credits, and includes weekly seminars and summer plant tours and projects.

## Graduate Courses

**421. Managing the Manufacturing Life Cycle (3)**
Manufacturing as an integrated technical-social-economic system. Linkages between corporate and manufacturing strategies. Combines a systems perspective with project leadership and membership skills for introducing and managing change into manufacturing systems at various life cycle stages.

**423. Product Design/Analysis (3)**
Integrated approach to design and analysis of products and systems. Principles for robust design and use of computer-aided engineering to model, evaluate, and enhance design. Case studies and design assignments.

**425. Production Planning and Resource Allocation (3)**
Capacity planning, scheduling, inventory control, and other topics in the management of manufacturing resources. Discrete and continuous simulation models for analysis and design of production systems. Factory information systems and data bases for computer integrated manufacturing.

**427. Production Systems (3)**
Modern production and assembly methods used in the mechanical and electrical/electronics industries. Techniques for deciding the most appropriate production method for a new product. Computer-aided process planning, group technology, robotics, numerical control, and other automated manufacturing methods.

**431. Technological Innovation in the Manufacturing Organization (3)**
Organizational issues and decision-making for capital investments in new technologies. The commercialization process is traced from research and development and marketing activities through the implementation phase involving the manufacturing function. Term project is a commercialization plan for a new manufacturing technology.

**433. Technology and the Factory of the Future (3)**
Engineering and technological issues affecting future developments in manufacturing. Topics include flexible automation systems, integration of design and production through the factory data network, intelligent machines, the man-machine interface, and the manufacturing management information system.

**451. Manufacturing Systems Engineering Project (1-3)**
Eight-week project work involving the solution of a problem in manufacturing systems engineering. A written report is required.

**490. Manufacturing Systems Engineering Thesis (1-6)**
Students will conduct MSE thesis research beginning in the summer. Students will continue their thesis research in the fall semester.

# Marketing

**Professor.** Raymond L. Horton, D.B.A. (Indiana).
**Associate professors.** James E. Hansz, Ph.D. (Cincinnati), *chairman*; Bruce M. Smackey, Ph.D. (Rensselaer).
**Assistant professors.** James M. Maskulka, D.B.A. (Kent State); Therese A. Maskulka, D.B.A. (Kent State).

The marketing major in the College of Business and Economics consists of fifteen credit hours from the following courses:

**Required courses**

| | |
|---|---|
| Mkt 312 | Marketing Research (3) |
| Mkt 313 | Marketing Communications (3) |

**Elective courses**

Three courses (nine credit hours) from the following:

| | |
|---|---|
| Mkt 315 | Consumer Behavior (3) |
| Mkt 316 | Advertising (3) |
| Mkt 319 | New Product Planning (3) |
| Mkt 320 | International Marketing (3) |
| Mkt 321 | Marketing in the Industrial Environment (3) |
| Mkt 330 | Retail Management (3) |
| Mkt 371 | Directed Readings (1-3) |
| Mkt 372 | Special Topics (1-3) |

Other approved courses may be used as marketing electives depending upon student's career orientation.

## For Advanced Undergraduates and Graduate Students

**Mkt 211. Contemporary Marketing (3)** fall-spring
The course examines contemporary marketing from a managerial perspective. Design of marketing programs within the context of consumer behavior, the social, economic, and cultural environment, market segmentation, demand, and industry structure. Prerequisite: Eco 1.

**Mkt 312. Marketing Research (3)** fall-spring
Quantitative and qualitative information in routine and nonrecurring decision-making. Statistical design of marketing studies, model building, analysis of research studies, and the development of marketing information systems. Case problems and presentation of student research projects examine problems in communicating research results. Prerequisites: Eco 145 and Mkt 211. Hansz, Horton, Smackey

**Mkt 313. Marketing Communications (3)** fall-spring
Communication-promotion decision processes of organizations. Impact of source, message and media variables on audience response to communication campaigns and the interactions among these variables. Role of personal selling, sales promotion, publicity, and advertising in marketing. Prerequisite: Mkt 211. Horton, T. Maskulka

**Mkt 315. Consumer Behavior (3)** fall-spring
Principal theories of psychology, social psychology, anthropology and economics which contribute to understanding the behavior and motivations of consumers. Consumer needs and wants; learning theory; the perceptual process; decision-making processes; communication; search behavior; market segmentation and product differentiation; and the adoption and diffusion of innovations. Prerequisite: Mkt 211 and Mkt 312. Horton

**Mkt 316. Advertising (3)** fall-spring
Analysis of advertising campaigns and the societal implications of advertising are considered from a managerial perspective. Prerequisite: Mkt 313. J. Maskulka

**Mkt 319. New Product Planning (3)** spring
Organization and management of marketing activities related to the development of new and improved products and services. The role of marketing research and product testing in the commercialization process. Application of risk analysis to the screening of ideas for new product candidates. Prerequisites: Mkt 211 and Fin 225. Smackey

**Mkt 320. International Marketing (3)** spring
The foreign market entry strategies firms may use are examined: export, contractual arrangements, and investment. Student

companies implement each strategy on a multinational business game. Prerequisites: Fin 225 and Mkt 211. Hansz, J. Maskulka

**Mkt 321. Marketing in the Industrial Environment (3)** fall
Strategies and problems in marketing industrial products and services. Role of a direct sales force and development of consultative sales approach in industrial marketing. Prerequisites: Fin 225 and Mkt 211. Smackey

**Mkt 330. Retail Management (3)** fall
Full coverage of all major retailing topics including consumer behavior, marketing research, store location, service retailing, the retail audit, retail institutions, and international retailing. Students work in groups to conceptualize and develop a retail store of their choice. Prerequisites: Mkt 211 and Mkt 312. T. Maskulka

**Mkt 371. Directed Readings (1-3)**
Readings in various fields of marketing designed for the student who has a special interest in some field of marketing not covered in regularly scheduled courses. Prerequisite: consent of the department chairperson. May be repeated.

**Mkt 372. Special Topics (1-3)**
Special problems and issues in marketing for which no regularly scheduled coursework exists. When offered as group study, coverage will vary according to the interests of the instructor and students. Prerequisite: consent of the department chairperson. May be repeated.

## For Graduate Students

**Mkt 411. Marketing and the Multinational Firm (3)**
Stages in the development of multinational firms are developed from initial use of marketing intermediaries, through the evolution of overseas production and marketing, to the eventual integration of the multinational firm. Student companies progress through each stage utilizing the medium of computer simulation. Prerequisites: Fin 411 and Mkt 413. Hansz, J. Maskulka

**Mkt 413. Marketing Management (3)** fall-spring
Planning and managing marketing activities: market analysis, buyer behavior, market segmentation, marketing research, product policy and strategy, distribution channels policy, advertising, and sales force management. Prerequisite: Eco 408 (or concurrently). Hansz, J. Maskulka

**Mkt 433. Strategic Marketing (3)** spring
The roles of customer functions served, customer groups served, and technologies utilized in defining their business are considered. Students perform a marketing audit and develop a marketing plan. Prerequisite: Mkt 413. Hansz, J. Maskulka, T. Maskulka, Smackey

**Mkt 435. Marketing Information and Decision-Making (3)** fall
Obtaining relevant marketing information for decision-making is examined from two perspectives: special projects and information systems. Student projects. Prerequisite: Mkt 413. Hansz

**Mkt 437. Advertising Management (3)** fall
Analysis of consumer and industrial advertising campaigns from a managerial perspective. Prerequisite: Mkt 413. J. Maskulka

**Mkt 439. Industrial Marketing and Sales Management (3)** fall
Marketing and sales problems associated with manufacturers of industrial products: organization and productivity of the sales force, product line policies, pricing strategies, buyer requirements, customer service, and formal proposals. Prerequisites: Fin 411 and Mkt 413. Smackey

**Mkt 441. Technological Innovation in Organizations (3)** spring
Analysis of problems associated with developing and marketing new products and processes in technologically oriented enterprises, from inception of idea to planning marketing strategies. Prerequisites: Fin 411 and Mkt 413. Smackey

**Mkt 443. Buyer Behavior and Marketing Management (3)** spring
Concepts, methodologies, and current research involving consumer and organizational buying behavior. Prerequisite: Mkt 413. Horton

**Mkt 445. Management of Sales Operations (3)** fall
Planning and organizing strategic sales programs; developing the sales force through recruitment, training, and motivation; control of sales programs through performance evaluation of sales personnel; and integrating sales with other marketing activities. Prerequisite: Mkt 413.

**Mkt 452. Causal Modeling (3)**
This course brings together in a single analytical framework two longstanding traditions: simultaneous equation modeling (regression analysis) and factor analysis (measurement models). Topics covered include measurement error, reliability, validity, confirmatiry factor analysis, and latent variable modeling. Prerequisites: Intermediate statistical theory or consent of department chairperson. Horton

**Mkt 462. Research Methodology (3)** spring, odd-numbered years
Criteria which distinguish scientific research from other significant human activities; development of concepts, laws and theories; general principles of research design; measurement theory; and scientific values and ethics. Students are expected to prepare a defensible dissertation proposal during the course. Open only to doctoral students. Horton

**Mkt 463. Advanced Data Analysis (3)** spring, even-numbered years
Applications oriented analysis of variance, regression analysis, and multi-variate analysis. SPSS, BMD, and other computer packages are used to analyze empirical data. Prerequisite: Intermediate statistics or permission of department chairperson. Horton

**Mkt 471. Directed Readings (1-3)**
Graduate reading in marketing not covered in regularly scheduled courses. When offered as group study, coverage varies according to the interests of the instructor and students. Prerequisite: consent of the chairperson. May be repeated.

**Mkt 472. Special Topics (1-3)**
Problems and issues in marketing for which no regularly scheduled graduate coursework exists. When offered as group study, coverage varies according to the interests of the instructor and students. Prerequisite: consent of the department chairperson. May be repeated.

# Materials Science and Engineering

**Professors.** Richard W. Hertzberg, Ph.D. (Lehigh), *New Jersey Zinc Professor, chairperson;* S. Kenneth Tarby, Ph.D. (Carnegie-Mellon), *associate chairperson;* Betzalel Avitzur, Ph.D. (Michigan), *director of Institute for Metal Forming;* Sidney R. Butler, Ph.D. (Penn State); Ye T. Chou, Ph.D. (Carnegie-Mellon); Joseph I. Goldstein, Sc.D. (M.I.T.), *Vice President for Research;* Walter C. Hahn, Jr., Ph.D. (Penn State); Martin P. Harmer, Ph.D. (Leeds, England); Ralph J. Jaccodine, Ph.D. (Notre Dame), *Sherman Fairchild Professor;* R. Wayne Kraft, Ph.D. (Michigan); Michael R. Notis, Ph.D. (Lehigh); Alan W. Pense, Ph.D. (Lehigh), *R. D. Stout Professor;* Donald M. Smyth, Ph.D. (M.I.T.), *director of Materials Research Center;* David A. Thomas, Sc.D. (M.I.T.), *Dean of Graduate Studies;* David B. Williams, Ph.D. (Cambridge); John D. Wood, Ph.D. (Lehigh).
**Associate professors.** Himanshu Jain, Engr.Sci.D. (Columbia); Charles E. Lyman, Ph.D. (M.I.T.).
**Assistant professor.** Helen M. Chan, Ph.D. (Imperial College of Science and Technology, England).
**Adjunct professors.** Brian R. Lawn, Ph.D. (Western Australia); Arnold R. Marder, Ph.D. (Lehigh); Gary A. Miller, Sc.D. (M.I.T.); Fumio S. Ohuchi, Ph.D. (Florida); James P. Snyder, Ph.D. (Lehigh); Seymour Traub, J.D. (Georgetown).
**Emeritus professors.** George P. Conard II, Sc.D. (M.I.T.); Joseph

F. Libsch, Sc.D. (M.I.T.); Robert D. Stout, Ph.D. (Lehigh).
**Research engineers and scientists.** Arlan O. Benscoter; Guy M. Connelly, M.S. (Lehigh); Dang-Rong Liu, Ph.D. (Cambridge).

As science and technology advance in the 1980s and beyond, progress in many fields will depend on the discovery and development of new materials, processed in more complex ways, and with new kinds of properties. This has recently been demonstrated nicely by the development of superconducting ceramic materials. It is widely recognized that the progress of history has been divided into periods characterized by the materials that mankind has used, i.e., the stone age, the bronze age, the iron age. Today, materials science and engineering is critical to all other fields of engineering, and advances in these other fields are often limited by advances in materials.

Interest in new materials for solid-state devices, space technology, and superconductivity, as well as a better understanding of the behavior of materials in the design of structures, automobiles and aircraft, plant processing equipment, electrical machinery, etc., have increased the need for people trained in science and technology of materials.

Education for this field of engineering requires basic studies in mathematics, chemistry, physics and mechanics, plus a general background in engineering principles, followed by intensive training in the application of scientific and engineering principles to the development and use of materials in a technological society. In addition, the curriculum offers an introduction to humanistic and social studies; these broaden the student's outlook and enhance professional development after graduation.

The undergraduate program is designed to train graduates for research, development, operations, management and sales careers in industry or for graduate study in various specialties of the field, including the manufacture and applications of metals, ceramics, polymers, composites, and electronic materials. While some graduates go directly into materials-producing companies, a large proportion serve as engineers in the chemical, electrical, transportation, communications, space and other materials consumer industries. A number of students pursue graduate study leading to careers in research and teaching.

## *Major Requirements*

The recommended sequence of courses is shown. The standard freshman engineering year is shown on page 37.

**sophomore year, first semester** (17 credits)*

| | |
|---|---|
| Math 23 | Analytic Geometry and Calculus III (4) |
| Phys 21, 22 | Introductory Physics II and Laboratory (5) |
| Eco 1 | Economics (4) |
| Mat 63 | Engineering Materials and Processes (3) **or** |
| Mat 93 | Introduction to Solid State Materials (3) **or** |
| | General Studies elective (3) |
| Mat 10 | Materials Laboratory (1) |

*Mat 10 and Mat 63 or 93 are required and should normally be taken during the sophomore year. However, they may be taken in the first semester of the junior year.

**sophomore year, second semester** (15-16 credits)

| | |
|---|---|
| Math 205 | Linear Methods (3) **or** |
| Math 231 | Probability and Statistics (3) |
| ECE 81 | Principles of Electrical Engineering (4) **or** |
| Phys 31 | Introduction to Quantum Mechanics (3) |
| Mech 1 | Statics (3) |
| | General Studies elective (3) |
| Mat 63 | Engineering Materials and Processes (3) **or** |
| Mat 93 | Introduction to Solid State Materials (3) **or** |
| | General Studies elective (3) |

**junior year, first semester** (18 credits)

| | |
|---|---|
| ChE 60 | Unit Operations Survey (3) |
| Chem 207 | Metallic Elements (3) |
| Mech 11 | Mechanics of Materials (3) |
| Mat 207 | Crystal Structure and Atom Movements (3) |
| Mat 210 | Metallurgical Thermodynamics (3) |
| | General Studies elective (3) |

**junior year, second semester** (18 credits)

| | |
|---|---|
| Mat 101 | Professional Development (2) |
| Mat 208 | Phase Diagrams and Transformations (3) |
| Mat 212 | Electronic Behavior of Solids (3) |
| Mat 218 | Mechanical Behavior of Materials (3) |
| Mat 304 | Chemical Metallurgy (4) |
| | elective (3) |

**summer**

| | |
|---|---|
| Mat 100 | Industrial Employment |

**senior year, first semester** (18 credits)

| | |
|---|---|
| Mat 305 | Ferrous Production Metallurgy (3) |
| Mat 307 | Materials Engineering I (3) |
| Mat 313 | Materials Fabrication (3) |
| | engineering science elective (3)* |
| | electives (6) |

**senior year, second semester** (18 credits)

| | |
|---|---|
| Mat 338 | Materials Reports (3) |
| Mat 308 | Materials Engineering II (3) |
| | engineering science elective (3)* |
| | approved elective (3) |
| | General Studies elective (3) |
| | elective (3) |

*Engineering science electives are selected from a list available in the department office.

In addition to the regular program, there are two options in the curriculum oriented to emphasize the following: industrial materials engineering, and preparation for graduate research in materials.

## *Industrial Option*

The industrial option is designed to prepare students in a four-year program as plant materials engineers. To assist in this objective, students electing the option take two special courses, Mat 327 and 329, in place of an equivalent number of other specified courses. The emphasis in these courses is a team approach to the solution of actual plant problems.

The course is conducted in cooperation with local industries. Three days per week are spent at the plant of the cooperating industry on investigations of selected problems. The option is limited to a small group of seniors, selected by the department from those who apply. Summer employment is provided when possible for those who elect to initiate the program during the summer preceding the senior year.

**junior year**
same as regular program

**summer**

| | |
|---|---|
| Mat 100 | Industrial Employment |

**senior year, first semester** (20 credits)

| | |
|---|---|
| Mat 327 | Industrial Project (4) |
| Mat 329 | Industrial Project (4) |
| Mat 305 | Ferrous Production Metallurgy (3) |
| Mat 307 | Materials Engineering I (3) |
| Mat 313 | Materials Fabrication (3) |
| | elective (3) |

**senior year, second semester** (17 credits)

| | |
|---|---|
| Mat 338 | Materials Reports (2) |

| | |
|---|---|
| Mat 308 | Materials Engineering II (3) |
| | approved elective (3) |
| | General Studies elective (3) |
| | engineering science electives (6)* |

*Engineering science electives are selected from a list available in the department office.

### *Research Option*

For those students who may be interested in research or development, and intend to pursue graduate work, a research option is offered. In this option, students take Mat 240 and 291. Financial support may be available for those students who elect to initiate a research program during the summer preceeding the senior year. The option is limited to a small group of selected students.

**junior year, second semester** (20 credits)
same as regular program with the following addition:

| | |
|---|---|
| Mat 240 | Research Techniques (2) |

**summer**

| | |
|---|---|
| Mat 100 | Industrial Employment or |
| | Undergraduate Summer Research |

**senior year, first semester** (18 credits)

| | |
|---|---|
| Mat 291 | Undergraduate Research (3) |
| Mat 305 | Ferrous Production Metallurgy (3) |
| Mat 307 | Materials Engineering I (3) |
| Mat 313 | Materials Fabrication (3) |
| | electives (6) |

**senior year, second semester** (17 credits)

| | |
|---|---|
| Mat 338 | Materials Reports (2) |
| Mat 308 | Materials Engineering II (3) |
| | Approved elective (3) |
| | General Studies elective (3) |
| | engineering science electives (6)* |

*Engineering science electives all selected from a list available in the department office.

## Undergraduate Courses

**10. Materials Laboratory (1)** fall
Application of equipment for laboratory study of structure and properties of materials. Prerequisite: Mat 63 or 93 previously or concurrently.

**63. Engineering Materials and Processes (3)** fall-spring*
Application of physical and chemical principles to understanding, selection, and fabrication of engineering materials. Materials considered include metals, polymers, ceramics, composites and electronic materials. Case studies of materials used range from transportation systems to microelectronic devices.

**92. Structure and Properties of Materials (3)** spring*
A unified chemical-physical approach to the structure and properties of metallic, nonmetallic and composite materials of construction. Laboratories and lecture examples emphasizing structure, mechanical properties, and material applications. Prerequisite: Chem 21, Phys 21.

**93. Introduction to Solid State Materials (3)** fall-spring*
The physical and mechanical behavior of all classes of materials, including those for solid state electronic applications. Atomic, crystallographic, molecular, and microstructures. The influence of heat treatment and mechanical and chemical processing on structure and properties. Pertinent examples of various applications of materials in advanced technologies. Prerequisite: Chem 21, Phys 21 previously or concurrently.

**Only one of these courses may be applied for graduation credit by each student.*

**100. Industrial Employment**
In the summer following the junior year, students in materials science and engineering are required to secure at least eight weeks of experience in industrial plants or research organizations. A written report is required.

**101. Professional Development (2)** spring
Seminar on the role and purpose of engineering in society; the meaning of being a professional; the role of creativity, communications and decision making in the engineering process; expectations and problems of young engineers; personal goals; choosing a career. Required reading. Written reports based on library research. Prerequisite: junior standing.

## For Advanced Undergraduates and Graduate Students

**207. Crystal Structure and Atom Movements (3)** fall
The crystalline state, imperfections, and noncrystalline state of materials. Study of structure by microscopy and x-ray diffraction. Atom movements and diffusion in solids. Prerequisite: Mat 10, previously or concurrently, and Phys 21.

**208. Phase Diagrams and Transformations (3)** spring
Thermodynamic basis for equilibrium. The phase rule. Equilibrium phase diagrams and nonequilibrium considerations, Solidification and solid-state phase changes. Rationalizations of microstructures. Recovery, recrystallization, and grain growth. Lectures and laboratory. Prerequisites: Mat 63 or 93; Mat 207 and Mat 210. Williams

**210. Metallurgical Thermodynamics (3)** fall
The applications of thermodynamic relations to metallurgical processes with emphasis on solving specific problems for processes such as metal refining, heat treating atmospheres, alloy equilibrium diagrams and others. Lectures and problem sections. Prerequisite: Math 23. Hahn

**212. Electronic Behavior of solids (3)** spring
Wave mechanical description of electrons in solids. Energy bands, zone theory. Conductivity and magnetism in metals, semiconductors and insulators. Selected engineering applications. Prerequisite: Phys 21, Mat 93 or 207. Butler

**213. Materials Systems Analysis (3)**
Study of application of materials science principles to the solution of materials engineering problems. Interrelation between basic concepts and the selection of complete materials systems, which consist of the fabricating process and finishing sequence, for particular design requirements. Materials covered will be metals, polymers, ceramics and composites. Not open to materials majors. Lectures and laboratory. Prerequisite: Mat 63 or equivalent. Wood

**215. Processing and Properties of Ceramic Materials (3)**
An introductory-level course on ceramic materials with emphasis on processing. Basic science of ceramic fabrication technology including glass, refractories, and ceramic coatings. Structure of oxides including clay minerals. Methods of characterization. Electrical, magnetic, thermal, and mechanical properties of ceramic products. Prerequisites: Chem 21, Phys 11 and Mat 63 or 93. Harmer

**218. Mechanical Behavior of Materials (3)** spring
Deformation and fracture behavior of materials. Elastic and plastic behavior, with emphasis on crystallographic considerations. Strengthening mechanisms in solids. Static and time-dependent fracture from metallurgical and fracture mechanics viewpoints. Fatigue failure. Prerequisites: Mech 11, Mat 207, and Mat 63 or Mat 93. Hertzberg

**221. (STS 221) Materials in the Development of Man (3)**
Development of materials technology and engineering from the stone age to atomic age as an example of the interaction between technology and society. In-class demonstration laboratories on composition and structure of materials. Term projects using archaeological materials and alloys. Course intended for, but not

limited to, students in the humanities and secondary science education. Engineering students may not use this course for engineering science or technical elective credit. Notis

**240. Research Techniques (2)** spring
Study and application of methods of materials research. Design of experimental programs, analysis of data, presentation of results. Restricted to small numbers of students selected by the department chairperson.

**291. Undergraduate Research (3)**
Application of research techniques to a project in materials science and engineering selected in consultation with the faculty. Normally preceded by Mat 240.

**304. Chemical Metallurgy (4)** spring
Study of the processes of the recovery and refining of metals and metalloids. Includes chemical principles, thermochemistry and kinetics. Phases in high-temperature metallurgical systems, refractories, and combustion of fuels. Lectures plus laboratory and computing methods. Prerequisites: ChE 60, Mat 210, and Engr 1 or equivalent. Hahn

**305. Ferrous Production Metallurgy (3)** fall
A detailed engineering analysis of iron and steel making processes. Thermodynamic and kinetic aspects of these processes. Development of mathematical models of processes by computer programming. Lectures, laboratory, and plant trips. Prerequisite: Mat 304. Tarby

**306. Optimization of Metallurgical Processes (3)**
Numerical methods are used to investigate metallurgical reactions and processes. Problems relating to the optimization of processes in the ferrous and nonferrous fields are studied. Lectures and computer-oriented problems. Prerequisite: a knowledge of computer programming and consent of the department chairperson. Tarby

**307. Materials Engineering I (3)** fall
Selection of fabrication sequences for ceramic, metallic and plastic materials. Correlation of structure and properties of ferrous alloys including design of thermal treatments. Lectures plus laboratory, which includes designing and conducting original experiments to solve materials engineering problems. Term project on selecting manufacturing sequences. Plant visits. A three-day inspection trip is required. Prerequisite: Mat 208. Pense, Wood

**308. Materials Engineering II (3)** spring
Continuation of Met 307. Correlation of structure and properties of ceramic and plastic materials. Design of nondestructive evaluation systems. Engineering to minimize environmental degradation of materials. Selection of materials and processing to solve specific engineering problems. Failure analysis. Lectures plus laboratory, which involves development and execution of experimental projects to solve engineering problems. Term project on selecting material systems. Plant visits. Prerequisite: Mat 307. Wood, Pense

**309. Composite Materials (3)** fall
The principles and technology of composite materials, primarily for structural use. Fabrication and properties of fiber-reinforced materials and other composites, such as laminates and foamed and fibrous thermal insulation. Lectures and some field trips or laboratories. Prerequisite: Mat 63 or equivalent. Thomas

**311. Metallic Materials for Structures (3)** fall
The structure and behavior of structural steels, aluminum and other alloys, with emphasis on materials used in large-scale engineering structures such as bridges, buildings and pressure vessels. Fracture mechanics concepts, the physical metallurgy of alloys involved, and fabrication of structures, especially welding. The relationship between materials, fracture control and fabrication. Materials majors may take only with the consent of the department chairperson. Lectures and laboratory. Hertzberg, Pense

**312. (ChE 312, Chem 312) Fundamentals of Corrosion (3)**
Corrosion phenomena and definitions. Electrochemical aspects including reaction mechanisms, thermodynamics, Pourbaix diagrams, kinetics of corrosion processes, polarization, and passivity. Nonelectrochemical corrosion including mechanisms, theories, and quantitative descriptions of atmospheric corrosion. Corrosion of metals under stress. Cathodic and anodic protection, coatings, alloys, inhibitors, and passivators. Prerequisite: Mat 210, Chem 187, or equivalent of either.

**313. Materials Fabrication (3)** fall
Basic concepts of stress, strain and stress-strain behavior under load. Analysis and description of metal forming, metal cutting, casting, joining, and powder metallurgy. Lectures and laboratory. Prerequisite: Mat 63 or equivalent. Avitzur

**314. Advanced Metal Forming (3)**
Extension of Met 313. Topics to be included: friction, lubrication and wear, failure and damage in metal forming, and deformation in composite metals and in powder metallurgy. Forming alternatives for specific products such as cans, tubes, wires and others will be compared. Recent developments of new forming processes. Prerequisite: Mat 313. Avitzur

**315. Physical Properties of Structural and Electronic Ceramics (3)**
Structure-property relationships in ceramics. Mechanical behavior including plasticity, hardness, elasticity, strength and toughening mechanisms. Thermal behavior including specific heat, thermal expansion, thermal conduction and thermal shock. Electrical behavior including application of tensors and crystal physics to electroceramics. Prerequisites: Chem 21 and Phys 11 and Mat 63 or Mat 92 or Mat 93. Harmer

**316. Physical Properties of Materials (3)**
Consideration of observed electrical, magnetic, thermal and optical properties of crystalline materials with emphasis on their relationship to electron configuration and crystal structure. Lectures and demonstrations. Prerequisite: Mat 207 or Phys 31, or consent of the department chairperson. Notis or Butler

**317. Imperfections in Crystals (3)**
The major types of crystal defects and their role in controlling the properties of materials. Point, line and planar defects, their atomic configurations and experimental techniques to study their characteristics. Emphasis on the role of dislocations and grain boundaries in the control of mechanical properties. Prerequisite: Mat 63 or 93, or equivalent. Chou and Williams

**319. Current Topics in Materials Science (3)**
Selected topics of current interest in the field of materials engineering but not covered in the regular courses. May be repeated for credit with consent of the department chairperson. Prerequisite: Mat 210 and 218.

**320. Analytical Methods in Materials Science (3)**
Selected topics in modern analysis and their application to materials problems in such areas as thermodynamics, crystallography, deformation and fracture, diffusion. Prerequisite: Math 231 or 205. Chou

**321. (ECE 305) Failure Analysis of Semiconductor Devices (3)**
Fundamental degradation and failure mechanisms that affect the reliability of semiconductor devices. The use of scanning and transmission electron microscopy to examine these mechanisms. Lectures and laboratory. Prerequisite: consent of department chairperson. Norian

**322. Materials Technology in the Energy Crisis (3)** spring
Impact of materials on energy including nuclear and solar energy and solar cells, coal gasification, MHD power generation and superconductors. Energy resources, conversion,and consumption. Materials limitations on development of energy alternatives in transportation, power and primary metals industries. Industry and government lecturers participate. Prerequisite: Mat 63 or consent of the department chairperson. Notis

**323. (ECE 303) Electrical and Physical Characterization of Defects in Semiconductors**
Basic concepts of solid-state physics applied to p-n junction theory. Topics will include influence of material growth techniques on defect origination; dislocations induced by diffusion; oxidation-induced

stacking faults; the role of imperfections on pipe leakage and soft breakdowns. The relation of materials, defects and processing will be highlighted. Jaccodine

**327. Industrial Project (4)** fall
Restricted to a small group of seniors and graduate students selected by the department from those who apply. Three full days per week are spent on development projects at the plant of an area industry, under the direction of a plant engineer and with faculty supervision. Hahn, Butler

**329. Industrial Project (4)** fall
To be taken concurrently with Mat 327. Course material is the same as Mat 327.

**333. (Geol 337, Chem 337) Crystallography and Diffraction (3)** fall
Introduction to crystal symmetry, point groups, and space groups. Emphasis on materials characterization by x-ray diffraction and electron diffraction. Specific topics include crystallographic notation, stereographic projections, orientation of single crystal, textures, phase identification, quantitative analysis, stress measurement, electron diffraction, ring and spot patterns, convergent beam electron diffraction (CBED), and space group determination. Applications in mineralogy, metallurgy, ceramics, microelectronics, polymers, and catalysts. Lectures and laboratory work. Prerequisites: Mat 207 or Geol 133 or senior standing in chemistry.

**334. (Geol 338) Electron Microscopy and Microanalysis (4)** fall
Fundamentals and experimental methods in electron optical techniques including scanning electron microscopy (SEM) conventional transmission (TEM) and scanning transmission (STEM) electron microscopy. Specific topics covered will include electron optics, electron beam interactions with solids, electron diffraction and chemical microanalysis. Applications to the study of the structure of materials are given. Prerequisite: consent of the department chairperson. Williams, Lyman

**335. (ChE 335) Principles of Semiconductor Materials Processing (3)** fall
Description and analysis of the processing steps involved in microelectronic material fabrication. Emphasis will be placed on the chemistry of the fabrication steps, mathematical modelling of the transport and chemical reaction phenomena, and interpretation of experimental methods and data. Prerequisite: a course in thermodynamics and senior standing.

**338. Materials Reports (2 or 3)** spring
Presentation of oral and written reports. Evaluation on both technical content and quality of presentation. Oral reports alone—2 credits; including written reports—3 credits. Prerequisite: senior standing.

**343. (ChE 393, Chem 393) Physical Polymer Science (3)**
Structural and physical aspects of polymers (organic, inorganic, natural). Molecular and atomic basis for polymer properties and behavior. Characteristics of glassy, crystalline and paracrystalline states (including viscoelastic and relaxation behavior) for single and multicomponent systems. Thermodynamics and kinetics of transition phenomena. Structure, morphology and behavior. Prerequisite: one year of physical chemistry.

**345. Nondestructive Evaluation (3)**
Scientific fundamentals and engineering applications of nondestructive evaluation methods including penetrant, magnetic particle, eddy-current, radiographic, ultrasonic and acoustic-emission inspection techniques. Recent developments in nondestructive inspection of materials. Lectures and labs. Prerequisite: Mat 63 or equivalent, senior standing. Wood

**396. (Chem 396) Chemistry of Nonmetallic Solids (3)**
Chemistry of ionic and electronic defects in nonmetallic solids and their influence on chemical and physical properties. Intrinsic and impurity-controlled defects, nonstoichiometric compounds, defect interaction. Properties to be discussed include; diffusion, sintering, ionic and electronic conductivity, solid-state reactions, and photoconductivity. Prerequisite: Chem 187 or Mat 210 or equivalent. Smyth

## For Graduate Students

The department offers three degrees; a master of science, a master of engineering, and a doctor of philosophy in science and materials engineering.

While a diversity of programs and curricula are available to a person interested in graduate study in the area of materials, generally the degree is earned in the department of materials science and engineering. However, thesis and dissertation research may be a part of programs under way in the department or at the Materials Research Center or other departments or centers.

The department has a large enough staff and graduate enrollment to enable it to suit the needs of students whose interests range from the science of materials through materials engineering. At the same time, those advanced students who want experience in teaching are able to teach under the guidance of the senior staff.

The foundation for successful graduate work in the department includes sound preparation in chemistry, physics and mathematics, and adequate breadth of general education. Candidates entering the department who have obtained their previous degrees in fields other than materials may be required to take certain undergraduate courses without credit toward the graduate degree.

The programs of the department are flexible. Upon acceptance, each student is assigned a faculty adviser. Under the adviser's direction, the student plans a course of study to satisfy individual needs and interests.

Most advanced-degree recipients find careers in industry or industrial or governmental research and development laboratories. A smaller number have gone into teaching, consulting or academic research.

Graduate facilities for research are located in the Whitaker Laboratory, in the interdisciplinary Materials Research Center, the Sherman Fairchild Laboratory, and other associated laboratories. The laboratories are well equipped with both generalized equipment as well as sophisticated research equipment.

Specialized equipment such as conventional and scanning transmission electron microscopes, scanning electron microscopes, electron microprobe, X-ray diffraction units, closed-loop mechanical testing equipment, and crystal-growing and zone-processing equipment are maintained and operated by skilled technicians. After receiving the required instructions, graduate students operate this equipment.

Departmental facilities are supplemented by central computer facilities, microcomputers, and a fine science and engineering library.

### *Special Programs and Opportunities*

The department has established specific recommended programs for the M.S., the M.Eng., and the Ph.D., emphasizing the following areas: electron microscopy and microanalysis of all materials, physical metallurgy, ceramics, polymers and composites, mechanical behavior, electronic materials, and manufacturing processes.

These programs are flexible. Students in an area such as fracture may work in the department or in cooperation with the Materials Research Center or the department of mechanical engineering. The ceramics program emphasizes the study of the electrical and mechanical behavior of various ceramic systems. The study of solid-state materials for electronic applications is done largely in the Sherman Fairchild Laboratory. The department also cooperates with the chemical engineering and chemistry departments in the graduate Polymer Science and Engineering Program.

### *Major Requirements*

The Graduate School requirements are explained in Section IV. In the department of materials science and engineering, a candidate for the M.S. completes a thesis. This normally represents six of the thirty semester hours required for this degree. Candidates for the M.Eng. complete a three-credit engineering project.

A candidate for the Ph.D. prepares a preliminary program of courses and research, providing for specialization in some phase of the field (largely through research) in consultation with the adviser.

Prior to formal establishment of the doctoral program by the special committee and its approval by The Graduate School, the student passes a qualifying examination that must be taken early in the first year of doctoral work. The department does not require a foreign language. It does require preparation and defense of a research proposal as a portion of the general examination.

Of the courses listed above only those in the 300 series are available for graduate credit. There are many additional offerings in materials under the listings of other departments.

Most graduate students receive some form of financial aid. Several kinds of fellowships and assistantships are available. This type of aid generally provides for tuition, an allowance for experimental supplies, and a stipend. For details of graduate scholarships, fellowships and assistantships, please refer to Section IV.

## *Research Activities*

Graduate students conduct their research in facilities located in the department or the Materials Research Center, or other centers and institutes. The following list of activities notes the many areas of interest. Asterisks (*) indicate research of an interdisciplinary nature.

**Materials science.** Crystal growth*; defect chemistry and electrical properties of insulating and semiconducting oxides*; growth and deformation of bicrystals; dislocation studies; meteorites and lunar materials; processing of metal insulator semiconductor structures and their evaluation and application to integrated circuits*; quantitative metallography; structure and behavior of solid-state materials.*

**Mechanical behavior.** Correlation of microstructure with mechanical behavior of low-alloy, high-strength steels; deep drawing, impact extrusion and ironing; electron fractography*; environmental crack kinetics*; fatigue crack propagation studies of metals and polymers*; flow through converging conical dies; friction measurement; theoretical analysis of metal-forming methods and correlation with metallurgical parameters; toughness of weld metal; weldability of steels.

**Ceramics.** Electrical properties of electronic ceramics*; hot pressing studies*; grain growth in oxides*; electrical and magnetic properties of oxides*; creep modeling of ceramics*; electron microscopy of dislocation structures*; defect chemistry and electrical properties of ceramic oxides and glasses*; deformation and fracture of structural ceramics and ceramic composites.*

**Physical metallurgy.** Brittle fracture characteristics and fatigue properties of low-alloy, high-strength steels*; diffusion-controlled growth; kinetics of solid-state reactions*; physical metallurgy of aluminum alloys; strengthening mechanisms; structure and morphology of martensite; ternary diffusion; transformation during joining; transmission electron microscopy of crystal defects.

**Polymers.** Environmental effects on polymers*; fatigue crack propagation in engineering plastics*; fracture surfaces of crystalline polymers*; ion transport in polymer membranes; mechanical behavior of interpenetrating networks*; mechanical behavior of polyvinyl chloride*; micromechanics of polymer fracture*; polymers from renewable resources; properties of polymer composites*; reclamation of scrap polymeric materials*; viscoelastic damping.

**Chemical metallurgy.** Mathematical modeling of metallurgical processes; thermodynamics of metallic solutions; thermodynamics and phase equilibria.

**Electronic materials.** Origin and properties of defects in semiconductors and insulators; processing of materials used in VLSI device structures, processes studied include ion implantation, rapid thermal processing, chemically enhanced oxidation, LPCVD, sputtering, and plasma etching and deposition.

## Graduate-Level Courses

**406. Solidification (3)**
Structure, theory and properties of liquids. Homogeneous and heterogeneous nucleation theory and experimental results. Solidification phenomena in pure, single and multiphase materials including the nature of the freezing interface, segregation, constitutional super-cooling, dendritic growth, crystallographic effects, the origin of defects, crystal growing, zone processes. Prerequisite: consent of the chairperson. Kraft

**407. Theory of Alloy Phases (3)**
Equilibrium portrayal and prediction. For the former, the emphasis is on systems of three of more independent variables. For the latter, consideration is given to the various factors, both 'physical' and thermodynamic, which influence, and may permit prediction of, equilibrium phase structures and their range of stability. Examples are considered of the extension of such approaches to property prediction. Prerequisite: an undergraduate course in equilibrium diagrams, e.g. Mat 208.

**408. Transformations (3)** fall
The thermodynamic, kinetic and phenomenological aspects of a wide spectrum of solid-state phase transformations. Theories of nucleation, growth and coarsening of second-phase precipitates. Application of the theories to continuous and discontinuous reactions, massive, martensitic and bainitic transformations in metals. Transformations in non-metallics. Prerequisite: Mat 208 and 210 or equivalent. Marder

**409. Current Topics in Materials (3)**
Recent practical and theoretical developments in materials. This course may be repeated for credit if new material is covered. Prerequisite: consent of the department chairperson.

**410. Physical Chemistry of Metals I (3)** fall
Discussions of reactions involving gases and reactions involving pure condensed phases and a gaseous phase. Ellingham diagrams and equilibria in metal-oxygen-carbon systems. Consideration of the behavior of solutions and methods for determining thermodynamic properties of solutions by experimentation and computation. Prerequisite: Mat 210 or equivalent. Tarby

**411. Modern Joining Methods (3)**
The foundations upon which the joining processes rest; the present limitations of the various processes; the trends in new developments; the engineering and structural aspects of joining. Prerequisite: Mat 208 and 218 or equivalent. Pense

**412. Magnetic Properties of Materials (3)**
Fundamental concepts of magnetism and magnetic properties of ferro- and ferrimagnetic materials. Metallic and nonmetallic materials. Current application areas considered as examples. Prerequisite: Phys 31 or 363 or equivalent. Butler or Notis

**413. Analysis of Metal Forming Processes (3)**
Three-dimensional stress and strain analysis. Yield criteria, plastic flow and the upper and lower bound theorems. Analysis of metal forming processes, including drawing and extrusion, press work, rolling and spinning. The emphasis is on presenting several approaches to each problem. Avitzur

**414. Physical Chemistry of Metals II (3)** spring
Presentation of free energy-composition and phase diagrams of binary systems. Evaluation of lattice stability parameters. Consideration of reaction equilibria in systems containing components in condensed solutions, including compound formation, oxide phases of variable composition, solubility of gases in metals. Alternative standard states and interaction parameters for solutions. Prerequisite: Mat 410. Tarby

**415. Mechanical Behavior of Ceramic Solids (3)**
Strength, elasticity, creep, thermal stress fracture, hardness, abrasion and high-temperature deformation characteristics of single- and multi-component brittle ceramic solids. Statistical theories of strength, static and cyclic fatigue, crack propagation, fracture toughness. Correlation of mechanical behavior, microstructure, and processing parameters. Prerequisite: Mat 218 or consent of the department chairperson. Notis, Harmer

**416. Atom Movements (3)**
Phenomenological and atomistic development of the laws of diffusion and their solution. Influence of gradients of concentration, potential, temperature and pressure. Effects of structural defects on diffusion in metals and nonmetals. Prerequisite: Math 23 and Chem 196 or the equivalent.

**417. Deformation and Strength of Solids (3)**
Topics related to deformation of solids including creep, strengthening mechanisms, annealing of deformed solids, preferred orientation. Primary emphasis is on crystalline materials. May be repeated for credit if different material is covered. Prerequisite: Mat 218 or equivalent. Chou, Hertzberg, Kraft or Notis

**418. Fatigue and Fracture of Engineering Materials (3) fall**
Application of fracture mechanics concepts to the fatigue and fracture of crystalline and amorphous solids. Fracture control design philosophies. Metallurgical aspects of fracture toughness and embrittlement susceptibility. Environment-enhanced cracking. Fatigue crack propagation in metals and polymers. Electron fractography. Failure analysis case histories. Prerequisite: Mat 218 or equivalent. Hertzberg

**419. Advanced Physical Metallurgy (3)**
Application of physical metallurgy principles to materials systems. Transformation structures and the influence of morphology on properties. Alloy design and heat treatment for improved strength, toughness, creep, corrosion resistance, electrical and magnetic properties. Prerequisite: Mat 307 or equivalent. Marder

**421. Fracture Analysis (3)**
Application of fracture mechanics concepts, microstructural analysis, and fracture surface characterization to the analysis and prevention of engineering component failures. Extensive use of case histories. Introduction to legal aspects of product liability. Prerequisite: Mat 218 or 311 or Mech 313 or equivalent. Hertzberg

**422. Electrical Properties of Materials (3)**
Electrical transport properties of metallic, semiconducting and insulating materials. Brief review of energy band concepts including surface and contact effects. Photoconduction and contact phenomena. Prerequisite: Phys 31 or 363 or equivalent. Butler or Notis

**423. Advanced Transmission Electron Microscopy (3)**
The theory and practice of operation of the transmission and scanning transmission electron microscope. Techniques covered include bright field, high resolution and weak-beam dark field, lattice imaging, diffraction pattern indexing and Kikuchi line analysis. The theory of diffraction contrast is applied to the interpretation of electron micrographs. Specimen preparation techniques. Prerequisite: Mat 334 or equivalent. Williams

**425. Topics in Materials Processing (3)**
Topics such as: ceramics, metal, and polymer synthesis and compaction phenomena. Theories of sintering and grain growth. Physical behavior of sintered compacts. Techniques of fiber and crystal growth. Vapor deposition and ultra-high-purity materials preparation. Desirable preparation: Mat 208, 218, 315. Prerequisite: consent of the department chairperson.

**427. Advanced Scanning Electron Microscopy (3)**
The theory and practice of operation of the scanning electron microscope and electron microprobe. Techniques covered will include high-resolution scanning, quantitative electron probe microanalysis. Electron beam sample interactions, X-ray spectrometry, and electron optics will be discussed in detail. Prerequisite: Mat 334 or equivalent.

**429. Dielectric and Electrical Properties of Ceramics (3)**
Basic concepts of dielectric and electrical phenomena in ceramics including dielectric loss, dielectric breakdown, ferroelectricity, piezoelectricity, mixed conduction, and interfacial effects. Physical and materials aspects of technologically important ceramics such as thermistors, varistors, boundary layer capacitors, solid electrolytes, gas sensors, glasses etc. Prerequisite: Mat 212 or equivalent. Jain

**430. Glass Science (3)**
Definition and formation of glass. Structure of common inorganic (including metallic) and polymeric glass systems. Methods of glass making. Phase separation of devitrification. Physical properties including diffusion, electrical conductivity, chemical durability, and optical and mechanical properties. Special products including glass ceramics, optical fibers, photosensitive glasses, etc. Visit to a glass manufacturing plant may also be included. Prerequisite: Mat 315 or equivalent. Jain

**431. Sintering Theory and Practice (3)**
Science and technology of the sintering of solid state materials. Driving force and variables. Critical review of the sintering models. Coverage of single phase, multiphase and composite systems. Special sintering techniques such as fast firing, rate controlled sintering, hot pressing and transient second phase sintering. Sintering of specific ceramic and metal systems. Prerequisite: Mat 215 or equivalent. Harmer

**437. (Mech 437) Dislocations and Strength in Crystals (3)**
Theory and application of dislocations. Geometrical interpretation; elastic properties; force on a dislocation; dislocation interactions and reactions; multiplication. Dislocations in crystal structures. Selected topics in strengthening, plastic flow, creep, fatigue and fracture are discussed. Prerequisite: Math 205 or 231, or Mat 320; Mat 317, or consent of the department chairperson. Chou, Wei

**443. (Chem 443) Solid-State Chemistry (3)**
Crystal structure, diffraction in crystals and on surfaces, bonding and energy spectra in solids, dielectrics, surface states and surface fields in crystals. Prerequisite: Chem 191 or equivalent. Klier

**458. Materials Design (3)**
Analysis of design requirements for materials components. Selection of materials and processes. Study of failures in process and service and application of recent metallurgical and materials engineering knowledge for improved design. Solution and discussion of industrial problems, and outline of experimental approach. Prerequisite: consent of the chairperson. Wood

**460. Engineering Project (1-3)**
In-depth study of a problem in the area of materials engineering or design. The study is to lead to specific conclusions and be embodied in a written report. Intended for candidates for the M.Eng. May be repeated for a total of three credit hours.

**461. Advanced Materials Research Techniques (3)**
Study of the theory and application of selected advanced techniques for investigating the structure and properties of materials. May be repeated for credit with the approval of the department chairperson.

**482. (Chem 482, ChE 482) Engineering Behavior of Polymers (3) spring**
A treatment of the mechanical behavior of polymers. Characterization of experimentally observed viscoelastic response of polymeric solids with the aid of mechanical model analogs. Topics include time-temperature superposition, experimental characterization of large deformation and fracture processes, polymer adhesion, and the effects of fillers, plasticizers, moisture and aging on mechanical behavior.

**485. (Chem 485, ChE 485) Polymer Blends and Composites (3) fall**
An intensive study of the synthesis, morphology, and mechanical behavior of polymer blends and composites. Mechanical blends, block and graft copolymers, interpenetrating polymer networks, polymer impregnated concrete, and fiber and particulate reinforced polymers are emphasized. Prerequisite: any introductory polymer course or equivalent.

# Mathematics

**Professors.** Edward F. Assmus, Jr., Ph.D. (Harvard); Donald M. Davis, Ph.D. (Stanford); Bennett Eisenberg, Ph.D. (M.I.T.); B. K. Ghosh, Ph.D. (London); Samuel L. Gulden, M.A. (Princeton); Samir A. Khabbaz, Ph.D. (Kansas); Jerry P. King, Ph.D. (Kentucky); Gregory T. McAllister, Ph.D. (Berkeley), *head of the Division of Applied Mathematics and Statistics;* George E. McCluskey, Ph.D. (Pennsylvania), *head of the Division of Astronomy;* Eric P. Salathe, Ph.D. (Brown), *director of the Institute*

*for Biomedical Engineering and Mathematical Biology;* Murray Schechter, Ph.D. (N.Y.U.); Gerald F. Smith, Ph.D. (Brown), *director of the Center for the Application of Mathematics;* Andrew K. Snyder, Ph.D. (Lehigh), *chairperson;* Gilbert A. Stengle, Ph.D. (Wisconsin); Albert Wilansky, Ph.D. (Brown), *University Distinguished Professor.*

**Associate professors.** Bruce A. Dodson, Ph.D. (S.U.N.Y. at Stony Brook); Wei-Min Huang, Ph.D. (Rochester); David L. Johnson, Ph.D. (M.I.T.); Jacob Y. Kazakia, Ph.D. (Lehigh); Clifford S. Queen, Ph.D. (Ohio State); Gerhard Rayna, Ph.D. (Princeton); Lee J. Stanley, Ph.D. (Berkeley); Ramamirtham Venkataraman, Ph.D. (Brown).

**Assistant professors.** Vladimir Dobric, Ph.D. (Zagreb, Yugoslavia); Penny D. Smith, Ph.D. (Polytechnic Institute of Brooklyn); Susan Szczepanski, Ph.D. (Rutgers); Joseph E. Yukich, Ph.D. (M.I.T.).

Mathematics is the universal language of science, and is essential for a clear and complete understanding of virtually all phenomena. Mathematical training prepares a student to express and analyze problems and relationships in a logical manner in a wide variety of disciplines including the physical, engineering, social, biological, and medical sciences, business, and pure mathematics itself. This is a principal reason behind the perpetual need and demand for mathematicians in education, research centers, government, and industry.

The department offers two major programs leading to the degrees of bachelor of arts in mathematics and bachelor of science in statistics. It also offers five minor programs for undergraduates.

The Division of Astronomy and the Division of Applied Mathematics and Statistics are parts of the Department of Mathematics. Details on these divisions may be found in separate listings in the catalog.

## *Calculus Sequences*

There are three calculus sequences: Math 21, 22, 23; Math 31, 32; Math 41, 44. The first sequence should be taken by those students who might go into engineering, mathematics or the natural and physical sciences. The first sequence will always be accepted in place of Math 41 and 44, but not vice versa. Math 41, 42, 43 and 44 are designed primarily for students of the biological, management, and social sciences (BMSS); Math 44 should normally be taken in the semester following Math 41, but Math 42 and 43 may be taken at any time. Math 31 and 32 constitute an accelerated calculus sequence that is at least equivalent to the Math 21, 22, 23 sequence. Enrollment in Math 31 and 32 is limited to those students who have demonstrated exceptional ability in pre-university mathematics. A grade of C− or better in Math 32 entitles a student to receive twelve credit hours for eight hours of work in Math 31 and 32. Credit will be awarded for only one course in each of the following three groups, A: 21, 31, 41, B: 22, 32, 44, C: 23, 32, when more than one course is taken in any group, credit will be given for the course with the maximum hours.

## *B.A. in Mathematics*

The B.A. program in mathematics emphasizes fundamental principles as well as the mastery of techniques required for the effective use of mathematics. The program has the flexibility and versatility needed to prepare students for careers in government, industry and education. The program provides a solid foundation for those who want to pursue advanced study in any mathematically oriented field.

The program involves a total of 120 credit hours, 42 of which are in required major courses listed below. The remaining 78 credit hours are for college and university requirements (page 28), general electives, and additional mathematics courses that a student may wish to take.

**Required Major Courses** (42 credit hours)

| | |
|---|---|
| Math 21, 22, 23 | Analytic Geometry and Calculus I, II and III (12) |
| Math 205 | Linear Methods (3) |
| Math 219, 220 | Principles of Analysis I and II (6) |
| Math 243 | Algebra (3) |
| Math 244 | Linear Algebra (3) |
| Math 316 | Complex Analysis (3) |
| Math | Electives (12) |

Note: Math 21, 22, 23 may be replaced by Math 31, 32. The twelve hours of electives must be approved by the student's major advisor. The electives must include at least two of the following courses: Math 230, 231, 303, 307, 320 and 342. A student must achieve an average of 2.0 or higher in major courses.

## *B.S. in Statistics*

Statistics is concerned with the development and application of techniques for collecting, analyzing and interpreting data in such a way that the reliability of the conclusions can be quantified. Statistical analysis thus forms a fundamental tool in all experimental sciences and is important in understanding chance phenomena. Mathematical principles, especially probability theory, underlie all statistical analyses.

The B.S. program in statistics is interdisciplinary, and is a cooperative effort of faculty members from several departments. A student participating in the program is enrolled in the department of mathematics and is assigned a faculty advisor whose departmental affiliation depends on the student's needs and interests.

The program involves a total of 120 credit hours, which are divided into four parts.

**College and University Requirements** (36 credit hours)
See page 28.

**Required Major Courses** (43 credit hours)

| | |
|---|---|
| Math 21, 22, 23 | Analytic Geometry and Calculus I, II and III (12) |
| Math 7 | Elements of Statistics (3) |
| Math 205 | Linear Methods (3) |
| Math 309 | Theory of Probability (3) |
| Math 310 | Probability and Its Applications (3) |
| Math 334 | Mathematical Statistics (3) |
| Math 374 | Statistical Project (3) |
| CSc 11 | Introduction to Structured Programming (3) |
| CSc 15 | Data Structures (4) |
| IE 333 | Sampling for Information (3) |
| IE 336 | Analysis of Experimental Data (3) |

Note: Math 21, 22, 23 may be replaced by Math 31, 32, and Math 7 may be replaced by Math 231 or Eco 145. A student must achieve an average of 2.0 or higher in major courses.

**Major Electives** (12 credit hours)
Four courses chosen from: Math 208, 219, 244, 313, 344, IE 206, 332, Mkt 463.

**Professional Electives** (29 credit hours)
These are to be selected from at least two fields of application of statistics and probability, such as biology, psychology, social relations, computer science, engineering, economics, and management.

The major and professional electives must be approved by the faculty advisor.

## *Minor Programs*

The department offers five minor programs in different branches of the mathematical sciences. The minors are designed to provide recognition to those students who take a program of study in mathematics or a related area in addition to their major requirements in the engineering, arts and science or business curricula.

Each program requires twelve credit hours of work shown below, and Math 23 or 32. For substitutions, the student should consult the chairman.

**Minor in Pure Mathematics**
Math 219, 243, 244
Math 220 or 303 or 307 or 316 or 342

**Minor in Applied Mathematics**
Math 205 or 244
Math 208, 322
Math 230 or 231 or 320 or 323 or 344

**Minor in probability and Statistics**
Math 7 and 309, or Math 42 and 231, or Math 231 and 309
Any two of Math 310, 313, 334

**Minor in Actuarial Science**
Math 205, 230, 231
Math 309 or 334 or 344
For information on examinations of actuarial societies, students may consult their minor advisor.

**Minor in Astronomy**
Phys 21, Astr 2
Astr 211 or 221
Astr 232 or 242

## Undergraduate Courses

**0. Precalculus (0)**
Review of the elementary mathematics needed to study calculus. No academic credit. Usually offered in the summer.

**5. Introduction to Mathematical Thought (3)** spring
Meaning, content, and methods of mathematical thought illustrated by topics that may be chosen from number theory, abstract algebra, combinatorics, finite or non-Euclidean geometries, game theory, mathematicallogic, set theory, topology.

**6. Introduction to Probability (3)** spring
Random phenomena, events, probability spaces; counting methods, conditional probability, independence; random variables and their probability laws; hypergeometric, binomial and Poisson distributions; uniform, exponential and normal densities. Applications to various fields.

**9. Introduction to Finite Mathematics (3)**
Systems of linear equations, matrices, introduction to linear programming. Sets, counting methods, probability, random variables, introduction to Markov chains.

**12. Statistical Methods (3)** fall
Statistical data and frequency distributions; random sampling; estimation, confidence intervals, hypothesis testing; correlation, regression; analysis of variance. Illustrations from biological, social, physical and engineering sciences. Prerequisite: Math 6 or 9 or consent of the department chairperson.

**21. Analytic Geometry and Calculus I (4)** fall-spring
Functions and graphs; limits and continuity; derivative, differential, and applications; Taylor's Theorem and other approximations; indefinite and definite integrals; trigonometric, logarithmic, exponential, and hyperbolic functions.

**22. Analytic Geometry and Calculus II (4)** fall-spring
Applications of integration; techniques of integration; separable differential equations; infinite sequences and series; curves and vectors in the plane. Prerequisite: Math 21 or Math 31.

**23. Analytic Geometry and Calculus III (4)** fall-spring
Vectors in space; partial derivatives; Lagrange multipliers; multiple integrals; vector analysis; exact differential equations and second-order differential equations with constant coefficients. Prerequisite: Math 22.

**31. Honors Calculus I (4)** fall
Functions and graphs; limits and continuity; derivative and differential; indefinite and definite integrals, logarithmic; exponential, trigonometric and hyperbolic functions; techniques and applications of integration. Math 31 may be used in place of Math 21 to satisfy prerequisites. Prerequisite: consent of the department chairman.

**32. Honors Calculus II (4)** spring
Vector calculus; solid analytic geometry; series; Taylor's Theorem; approximations; partial derivatives; multiple integrals; line and surface integrals; differential equations. Prerequisite: Math 31 or consent of the department chairman.

**41. BMSS Calculus I (3)** fall-spring
Functions including the exponential, logarithmic, and trigonometric functions; limits; continuity; differentiation with applications to maximum and minimum problems; antidifferentiation.

**43. BMSS Linear Algebra (3)** fall
Matrices, vectors, vector spaces and mathematical systems, special kinds of matrices, elementary matrix transformations, systems of linear equations, convex sets, introduction to linear programming.

**44. BMSS Calculus II (3)** fall-spring
Indefinite and definite integrals and the fundamental theorem of calculus with applications; numerical integration; elementary differential equations; functions of several variables and partial derivatives with applications to extremal problems. Prerequisite: Math 41 or Math 21 or consent of the department chairman.

**171. Readings (1-3)** fall-spring
Study of a topic in mathematics under individual supervision. Intended for students with specific interests in areas not covered in the listed courses. Prerequisite: consent of the department chairman.

## For Advanced Undergraduates and Graduate Students

*For students who have not taken their elementary mathematics at Lehigh, the prerequisites for certain advanced courses are stated in terms of the number of credit hours of calculus.*

**205. Linear Methods (3)** fall-spring
Linear differential equations and applications; matrices and systems of linear equations; vector spaces; eigenvalues and application to linear systems of differential equations. Prerequisite: Math 23 or Math 32 or nine semester hours of differential and integral calculus.

**207. (ChE 207) Introduction to Biomedical Engineering and Mathematical Physiology (3)** fall
Topics in human physiology and mathematical analysis of physiological phenomena, including the cardiovascular and respiratory systems, biomechanics, and renal physiology; broad survey of bioengineering. Independent study projects. Prerequisite: Math 205.

**208. Complex Variables (3)** fall-spring
Functions of a complex variable; calculus of residues; contour integration; applications to conformal mapping and Laplace transforms. Prerequisite: Math 23 or Math 32.

**219. Principles of Analysis I (3)** fall
Existence of limits, continuity and uniform continuity; Heine-Borel Theorem; existence of extreme values; mean value theorem and applications; conditions for existence of the Riemann integral; absolute and uniform convergence; emphasis on theoretical material from the calculus of one variable. Prerequisite: Math 23 or Math 32.

**220. Principles of Analysis II (3)** spring
Continuation of Math 219. Functions of several variables; line and surface integrals; implicit functions. Prerequisite: Math 219.

**230. Numerical Methods (3)** fall-spring
Representation of numbers and rounding error; numerical solution of equations; quadrature; polynomial and spline interpolation; numerical solution of initial and boundary value problems. Prerequisites: Math 205 (previously or concurrently) and knowledge of either FORTRAN or PASCAL.

**231. Probability and Statistics (3)** fall-spring
Probability and distribution of random variables; populations and random sampling; chi-square, t, and F distributions; estimation and tests of hypotheses; correlation and regression theory of two variables. Prerequisite: Math 23 or Math 32 or Math 44.

**237. Recursive Functions and the Theory of Computation (3)**
Core development of classical recursion theory, enumeration, index and recursion theorems, using a simple programming language as a model of computation. Other models of computation and Church's Thesis. Recursive operators and their fixed points.

**243. Algebra (3)** spring
Introduction to basic concepts of modern algebra: groups, rings, and fields.

**244. Linear Algebra (3)** fall
Thorough treatment of the solution of m simultaneous linear equations in n unknowns, including a discussion of the computational complexity of the calculation. Vector spaces, linear dependence, bases, orthogonality, eigenvalues. Application as time permits. Prerequisite: Math 43 or Math 205 or Math 243.

**261. (CSc 261) Discrete Structures (3)**
Topics in discrete mathematical structures chosen for their applicability to computer science and engineering. Sets, propositions, induction, recursion; combinatorics; binary relations and functions; ordering, lattices and Boolean algebra; graphs and trees; groups and homomorphisms. Prerequisites: Math 21, and either CSc 11 or Engr 1.

**303. Mathematical Logic (3)** fall
A course, on a mathematically mature level, designed not only to acquaint the student with logical techniques used in mathematics but also to present symbolic logic as an important adjunct to the study of the foundations of mathematics.

**304. Axiomatic Set Theory (3)** spring
A development of set theory from axioms; relations and functions; ordinal and cardinal arithmetic; recursion theorem; axiom of choice; independence questions. Prerequisite: Math 219 or consent of the department chairman.

**307. General Topology I (3)** fall
An introductory study of topological spaces, including metric spaces, separation and countability axioms, connectedness, compactness, product spaces, quotient spaces, function spaces. Prerequisite: Math 219.

**308. Algebraic Topology (3)** spring
Polyhedra, fundamental groups, simplicial and singular homology. Prerequisites: Math 307 and either Math 243 or Math 327.

**309. Theory of Probability (3)** fall
Probabilities of events on discrete and continuous sample spaces; random variables and probability distributions; expectations; transformations; simplest kind of law of large numbers and central limit theorem. The theory is applied to problems in physical and biological sciences. Prerequisite: Math 23 or Math 32 or Math 44.

**310. Probability and Its Applications (3)** spring
Continuation of Math 309. Random variables, characteristic functions, limit theorems; stochastic processes, Kolmogorov equations; Markov chains, random walks. Prerequisite: Math 309 or consent of the department chairman.

**313. Nonparametric Statistics (3)** fall
Order and rank statistics; tests based on runs, signs, ranks, and order statistics; chi-square and Kolmogorov-Simirnov tests for goodness of fit; the two-sample problem; confidence and tolerance intervals. Prerequisite: Math 231 or 309.

**316. Complex Analysis (3)** spring
Concept of analytic function from the points of view of the Cauchy-Riemann equations, power series, complex integration, and conformal mapping. Prerequisite: Math 219.

**320. Ordinary Differential Equations (3)** spring
The analytical and geometric theory of ordinary differential equations, including such topics as linear systems, systems in the complex plane, oscillation theory, stability theory, geometric theory of nonlinear systems, finite difference methods, general dynamical systems. Prerequisite: Math 205, or both Math 23 and Math 244.

**322. Methods of Applied Analysis I (3)** fall
Fourier series, eigenfunction expansions, Sturm-Liouville problems, Fourier integrals and their application to partial differential equations; special functions. Emphasis is on a wide variety of formal applications rather than logical development. Prerequisite: Math 205 or consent of the department chairman.

**323. Methods of Applied Analysis II (3)** spring
Green's functions; integral equations; variational methods; asymptotic expansions, method of saddle points; calculus of vector fields, exterior differential calculus. Prerequisite: Math 322.

**325. Computational Matrix Theory (3)**
Numerical matrix algebra; algorithms for solving linear systems; symmetric and non-symmetric eigenvalue problems; least squares; functions of matrices. Students will apply these methods using either FORTRAN or PASCAL. Prerequisites: Math 205 or Math 244, and knowledge of FORTRAN or PASCAL.

**327. Groups and Rings (3)** fall
An intensive study of the concepts of group theory including the Sylow theorems, and of ring theory including unique factorization domains and polynomial rings. Prerequisite: Math 243 or consent of the department chairman.

**334. Mathematical Statistics (3)** spring
Populations and random sampling; sampling distributions; theory of statistical estimation; criteria and methods of point and interval estimation; theory of testing statistical hypotheses. Prerequisite: Math 231 or Math 309.

**338. Regression Analysis (3)** spring
Least square principles in multiple regression and their interpretations; estimation, hypothesis testing, confidence and prediction intervals; residual analysis, multicollinearity, selection of regression models; comparison of data sets, analysis of variance and covariance, simultaneous inference procedures. Use of computer packages for statistical analysis. Prerequisite: Math 12 or 231.

**340. (CSc 340) Design and Analysis of Algorithms (3)** spring
Algorithms for searching, sorting, counting, graph and tree manipulation, matrix multiplication, scheduling, pattern matching and fast Fourier transforms. Abstract complexity measures and the intrinsic complexity of algorithms and problems in terms of asymptotic behavior; correctness of algorithms. Prerequisites: Math 23 and CSc 15, or consent of the department chairman.

**341. Mathematical Models and Their Formulation (3)** spring
Mathematical modelling of engineering and physical systems with examples drawn from diverse disciplines such as traffic flow, laser drilling, mold solidification, rocket design and business planning. Prerequisite: Math 205.

**342. Number Theory (3)**
A survey of elementary and nonelementary algebraic and analytic methods in the theory of numbers. Includes the Euclidean algorithm, Diophantine equations congruences, quadratic residues, primitive roots, number-theoretic functions as well as one or more of the following topics: distribution of primes, Pell's equation, Fermat's conjecture, partitions. Prerequisite: Math 219 or consent of the department chairman.

**344. Linear and Integer Programming (3)**
Origin of linear and integer programming problems. Solution of linear programming problems by the simplex algorithm and some of its variants. Duality theory. Solution of integer programming problems by cutting plane and branch and bound methods. Applications to economics, game theory and combinatorial problems. Prerequisite: Math 205, or both Math 23 and Math 244.

**347. Problem Solving (1)** fall-spring
Required of all first year graduate students. Emphasis on problems in analysis, linear algebra, and applications may be repeated for credit with consent of the department chairman. Prerequisites: Math 219 and Math 244.

**350. Special Topics (3)** fall-spring
A course covering special topics not sufficiently covered in listed courses. Prerequisite: consent of the department chairman. May be repeated for credit.

**371. Readings (1-3)** fall-spring
The study of a topic in mathematics under appropriate supervision, designed for the individual student who has studied extensively and whose interests lie in areas not covered in the listed courses. Prerequisite: consent of the department chairman. May be repeated for credit.

**374. Statistical Project (3)**
Supervised field project or independent reading in statistics or probability. Prerequisite: consent of the department chairman.

## Graduate Programs in Mathematics

The department offers graduate programs leading to the degrees of master of science in mathematics and the doctor of philosophy in mathematics.

To begin graduate work in mathematics a student must present evidence of adequate undergraduate preparation. The undergraduate program should have included a year of advanced calculus, a semester of linear algebra, and a semester of abstract algebra.

### *M.S. in Mathematics*

The master's program demands thirty credit hours of graduate courses with at least eighteen hours at the 400 level. With the permission of the chairman, up to six hours of these courses can be replaced by a thesis. All students in the master's program must also pass a comprehensive examination.

With a judicious choice of courses a student in the master's program can specialize in pure mathematics, applied mathematics, or statistics. The M.S. degree can serve both as a final degree in mathematics or as an appropriate background for the Ph.D. degree.

### *Ph.D. in Mathematics*

The plan of work toward the doctor of philosophy degree will include a comprehensive examination and a qualifying examination. The latter tests the student's command of some of the following areas: analysis, functional analysis, algebra, combinatorial theory, geometry, topology, probability, statistics, logic, numerical analysis, and differential equations. A general examination, a foreign language examination, and the doctoral dissertation and its defense complete the work for the Ph.D. degree.

The department accepts candidates for the Ph.D. who desire to specialize in any of the areas listed above. Each candidate's plan of work must be approved by a special committee of the department. Although there are no specific course requirements, the Ph.D. candidates normally take several courses related to their area of specialization.

## Graduate Programs in Applied Mathematics

See program description on page 49.

## Graduate Courses

**401. Real Analysis I (3)** fall
Metric spaces; Lebesgue measure, integration and differentiation; $L^p$ spaces; functions of bounded variation; and absolute continuity. Prerequisites: Math 220 and Math 307, or consent of the department chairman.

**402. Real Analysis II (3)** spring
Continuation of Math 401. Topics such as general theory of integration, Radon-Nikodym theorem, Fourier analysis, measures on topological space and Riesz representation theorems. Prerequisite: Math 401.

**404. Mathematical Logic (3)**
Topics in quantification theory relevant to formalized theories, recursive functions, Gödel's incompleteness theorem; algorithms and computability.

**405. Partial Differential Equations I (3)** fall
Classification of partial differential equations; methods of characteristics for first order equations; methods for representing solutions of the potential, heat, and wave equations, and properties of the solutions of these equations; maximum principles. Prerequisite: Math 220 or its equivalent.

**406. Partial Differential Equations II (3)** spring
Continuation of Math 405. Emphasis on second order equations with variable coefficients and systems of first order partial differential equations. Prerequisite: Math 405.

**409. Mathematics Seminar (1-6)** fall
An intensive study of some field of mathematics not offered in another course. Prerequisite: consent of the department chairman.

**410. Mathematics Seminar (1-6)** spring
Continuation of the field of study in Math 409 or the intensive study of a different field. Prerequisite: consent of the department chairman.

**414. Topics in Ordinary Differential Equations (3)**
Topics from the analytical and qualitative theory of differential equations and dynamical systems such as: structural stability, ordered chaos and strange attractors, bifurcation theory, normal forms, asymptotic methods, spectral theory of differential operators, boundary value problems. Prerequisite: consent of the department chairperson.

**416. Complex Function Theory (3)** fall
Continuation of Math 316. Prerequisite: Math 316 or consent of the department chairman.

**419. Linear Operators on Hilbert Space (3)**
Algebra and calculus of bounded and unbounded operators on Hilbert space; spectral analysis of self-adjoint, normal, and unitary operators. Interplay between operator theory and classical function theory is emphasized. Prerequisites: Math 220, and Math 208 or Math 316.

**423. Differential Geometry I (3)**
Differential manifolds, tangent vectors and differentials, submanifolds and the implicit function theorem. Lie groups and Lie algebras, homogeneous spaces. Tensor and exterior algebras, tensor fields and differential forms, de Rham cohomology, Stoke's theorem, the Hodge theorem. Prerequisite: Math 219, 220, or Math 243 or Math 244 or Math 205 with consent of instructor.

**424. Differential Geometry II (3)**
Curves and surfaces in Euclidean space; mean and Gaussian curvatures, covariant differentiation, parallelism, geodesics, Gauss-Bonnet formula. Riemannian metrics, connections, sectional curvature, generalized Gauss-Bonnet theorem. Further topics. Prerequisite: Math 423.

**428. Fields and Modules (3)** spring
Field theory, including an introduction to Galois theory; the theory of modules, including tensor products and classical algebras. Prerequisite: Math 327.

**430. Numerical Analysis (3)** spring
Multistep methods for ordinary differential equations; finite difference methods for partial differential equations; numerical approximation of functions. Use of computer required. Prerequisite: Math 230 or consent of the department chairman.

**431. Calculus of Variations (3)**
Existence of a relative minimum for single and multiple integral problems; variational inequalities of elliptic and parabolic types and methods of approximating a solution. Prerequisite: Math 220 or its equivalent.

**435. Functional Analysis I (3)** fall
Banach spaces and linear operators; separation and extension theorems; open mapping and uniform boundedness principles; weak topologies; local convexity and duality; Banach algebras; spectral theory of operators; and compact operators. Prerequisite: Math 401.

**436. Functional Analysis II (3)** spring
Continuation of Math 435. Topics such as distribution theory, nonlinear operators, fixed point theory and applications to classical analysis. Prerequisite: Math 435.

**443. General Topology II (3)**
Continuation of Math 307, with such topics as filters and nets, topological products, local compactness, paracompactness, metrizability, uniformity, function spaces, dimension theory. Prerequisite: Math 307.

**444. Algebraic Topology (3)**
Continuation of Math 308. Cohomology theory, products, duality. Prerequisite: Math 308.

**445. Topics in Algebraic Topology (3)**
Selected topics reflecting the interests of the professor and the students. Prerequisite: Math 444.

**449. Topics in Algebra (3)**
Intensive study of topics in algebra with emphasis on recent developments. Prerequisite: consent of the department chairman. May be repeated for credit with the consent of the department chairman.

**450. Special Topics (3)** fall-spring
Intensive study of some field of the mathematical sciences not covered in listed courses. Prerequisite: consent of the department chairman. May be repeated for credit with the consent of the department chairman.

**453. Function Theory (3)**
The development of one or more topics in function theory, such as analytic continuation, maximum modulus principle, conformal representation, Taylor series analysis, integral functions, Dirichlet series, functions of several complex variables. Prerequisite: Math 416.

**455. Topics in Number Theory (3)**
Selected topics in algebraic and analytic number theory. Prerequisites: Math 316 and Math 327. May be repeated for credit with consent of the department chairman.

**461. Topics in Mathematical Statistics (3)**
An intensive study of one or more topics such as theory of statistical tests, statistical estimation, regression, analysis of variance, nonparametric methods, stochastic approximation, and decision theory. Prerequisites: Math 334 and Math 401. May be repeated for credit with consent of the department chairman.

**463. Probability Theory (3)**
Measure theoretic and analytic methods used in probability; measure theoretic foundations of probability; convergence of random variables; weak convergence of probability measures; characteristic functions; limit theorems; conditional expectation; martingales; and foundations of the theory of stochastic processes. Prerequisites: Math 309 and Math 401.

**471. Homological Algebra (3)**
Modules, tensor products, categories and functions, homology functors, projective and injective modules. Prerequisite: Math 428.

**472. Group Representations (3)**
Linear representations and character theory with emphasis on the finite and compact cases. Prerequisite: Math 428 or consent of the department chairman.

**490. Thesis**

**499. Dissertation**

# Mechanical Engineering and Mechanics

**Professors.** Fazil Erdogan, Ph.D. (Lehigh), *chairman;* Robert G. Sarubbi, Ph.D. (Lehigh), *assistant chairman;* Russell E. Benner, Ph.D. (Lehigh); Philip A. Blythe, Ph.D. (Manchester, England), *Center for the Application of Mathematics;* Forbes T. Brown, Sc.D. (M.I.T.); Dominic G. Edelen, Ph.D. (Johns Hopkins), *Center for the Application of Mathematics;* Ronald J. Hartranft, Ph.D. (Lehigh); Stanley H. Johnson, Ph.D. (Berkeley); Arturs Kalnins, Ph.D. (Michigan); Edward K. Levy, Sc.D. (M.I.T.), *director, Energy Research Center;* Alister K. Macpherson, Ph.D. (Sydney, Australia); Jerzy A. Owczarek, Ph.D. (London, England); Richard Roberts, Ph.D. (Lehigh); Donald O. Rockwell, Ph.D. (Lehigh); Kenneth N. Sawyers, Ph.D. (Brown); George C.M. Sih, Ph.D. (Lehigh), *director, Institute for Fracture and Solid Mechanics;* Charles R. Smith, Ph.D. (Stanford); Gerald F. Smith, Ph.D. (Brown), *Center for the Application of Mathematics;* Theodore A. Terry, Ph.D. (Lehigh); Dean P. Updike, Ph.D. (Brown); Eric Varley, Ph.D. (Brown), *Center for the Application of Mathematics;* J. David A. Walker, Ph.D. (Western Ontario, Canada); Robert P. Wei, Ph.D. (Princeton).

**Associate professors.** Terry J. Delph, Ph.D. (Stanford); Gary D. Harlow, Ph.D. (Cornell); Jacob Y. Kazakia, Ph.D. (Lehigh), *Center for the Application of Mathematics;* Robert A. Lucas, Ph.D. (Lehigh); Sudhakar Neti, Ph.D. (Kentucky); John B. Ochs, Ph.D. (Penn State); Tulga M. Ozsoy, Ph.D. (Istanbul, Turkey); N. Duke Perreira, Ph.D. (California, Los Angeles); Kyra D. Stephanoff, D.Phil. (Oxford); Arkady Voloshin, Ph.D. (Tel-Aviv, Israel).

**Assistant professor.** Antonios Liakopoulos, Ph.D. (Florida).

**Adjunct professors.** Stanley J. Jakubowski, B.S. (Lehigh); Mustafa R. Ozgu, Ph.D. (Lehigh).

Engineering is a creative profession aimed at satisfying needs of society through the combination of material, human and economic resources. The programs in Mechanical Engineering and in Engineering Mechanics are designed so that students will be ready upon graduation to pursue satisfying and productive careers in a wide variety of fields. Separate degree programs are offered leading to the degrees of Bachelor of Science in Mechanical Engineering or Bachelor of Science in Engineering Mechanics.

Graduates in either degree are equipped for work in engineering, research and development and in government service or industry. Those with ability and interest have the necessary background to pursue further studies at the graduate level.

Because of the flexibility of the curriculum, candidates for either degree may combine the study of mechanical engineering or engineering mechanics with that of other fields, such as industrial engineering, chemical engineering, materials engineering, and biology, into interdisciplinary programs that will prepare them for further work in the areas of manufacturing, nuclear engineering, energy conversion and conservation, environmental engineering, materials engineering, or biomechanics.

Undergraduates become thoroughly familiar with Lehigh's computer-aided design (CAD) laboratory. The laboratory is a *teaching* facility and the technology is regarded as an engineering tool that can be applied to solving a wide variety of problems. Undergraduates not only use CAD in their coursework but some have developed interactive tutorials that help fellow students expand on and clarify material presented in class.

## B.S. in Mechanical Engineering

Mechanical Engineering is one of the broadest of the engineering professions, dealing generally with systems for energy conversion, material transport and the control of motions and forces.

Mechanical engineers may choose from among many different activities in their careers, according to their interests and the changing needs of society. Some concentrate on the conversion of thermal, nuclear, solar, chemical and electrical energy, or on the problems of air, water, and noise pollution. Some concentrate on the design of mechanical systems used in transportation, manufacturing or health care industries or by individual consumers. Some will be

working, a decade from now, in fields that do not yet exist. Most will be engaged with concepts involving all four dimensions, space and time.

The curriculum leading toward the bachelor of science in mechanical engineering combines a broad base in mathematics, physical sciences, and the engineering sciences (mechanics of solids, materials, dynamics and fluid, thermal and electrical sciences) with exposure to laboratory, the design process, computer-aided analysis and design, and specific applications fields. Much of the latter occurs in four or more courses elected toward the end of the program from a variety of offerings, which are identified by 300-level course designations. Courses in mechanical engineering and engineering mechanics are equally available.

The course requirements for B.S. degree in Mechanical Engineering are listed below. In addition to required Mathematics, Physics, Chemistry and basic engineering courses, the program includes 37 credits of general studies (page 00), two free electives and four approved electives. The total graduation requirement is 131 credits.

## Undergraduate Curriculum in Mechanical Engineering

**freshman year** (see page 37).

**sophomore year, first semester** (16 credit hours)

| | |
|---|---|
| Math 23 | Analytic Geometry and Calculus III (4) |
| Mech 1 | Statics (3) |
| Phys 21, 22 | Introductory Physics II and Laboratory (5) |
| ME 10 | Graphics for Engineering Design (4) |

**sophomore year, second semester** (17 credit hours)

| | |
|---|---|
| Math 205 | Linear Methods (3) |
| ME 104 | Thermodynamics I (3) |
| Mech 11 | Mechanics of Materials (3) |
| ME 21 | Mechanical Engineering Laboratory I (1) |
| Mat 63 | Engineering Materials and Processes (3) |
| Eco 1 | Economics (4) |

**junior year, first semester** (17 credit hours)

| | |
|---|---|
| Mech 102 | Dynamics (3) |
| ME 105 | Thermodynamics II (3) |
| ME 231 | Fluid Mechanics (3) |
| ECE 81 | Principles of Electrical Engineering (4) |
| ME 121 | Mechanical Engineering Laboratory II (1) |
| | general studies requirement (3) |

**junior year, second semester** (18 credits)

| | |
|---|---|
| ME 101 | Mechanical Engineering Design I (2) |
| ME 151 | Mechanical Elements (3) |
| Mech 203 | Advanced Strength of Materials (3) |
| ECE 162 | Electrical Laboratory (1) |
| ME 242 | Mechanical Vibrations (3) |
| Math 208 | Complex Variables (3) **or** |
| Math 231 | Probability and Statistics (3) |
| | general studies requirement (3) |

**senior year, first semester** (16 credit hours)

| | |
|---|---|
| ME 108 | Mechanical Engineering Laboratory III (2) **or** |
| ME 110 | Thesis (1-2) |
| ME 102 | Mechanical Engineering Design II (2) |
| ME 321 | Introduction to Heat Transfer (3) |
| | approved elective (3) |
| | general studies requirement (3) |
| | elective (3)* |

**senior year, second semester** (17 credit hours)

| | |
|---|---|
| ME 109 | Mechanical Engineering Laboratory IV (2) |
| | approved electives (9) |
| | general studies requirement (3) |
| | elective (3)* |

*Please refer to description of normal program, page 36.

Twelve credits of *APPROVED ELECTIVES* must be taken according to the following distribution.

At least one course (3 credits) from the following list of *engineering science electives*:

| | |
|---|---|
| ME 322 | Gas Dynamics (3) |
| ME 331 | Advanced Fluid Mechanics (3) |
| ME 343 | Control Systems (3) |
| Mech 302 | Advanced Dynamics (3) |
| Mech 305 | Advanced Mechanics of Materials (3) |

At least two courses (6 credits) from the following list of elective courses having *design or manufacturing content* with no more than one course (3 credits) being from outside Mechanical Engineering:

| | |
|---|---|
| ME 310 | Projects (1-3) |
| ME 312 | Synthesis of Mechanisms (3) |
| ME 323 | Reciprocating and Centrifugal Engines (3) |
| ME 327 | Coal Combustion and Conversion (3) |
| ME 329 | Solar Energy Conversion (3) |
| ME 340 | Advanced Mechanical Design (3) |
| ME 341 | Mechanical Systems (3) |
| ME 342 | Dynamics of Engineering Systems (3) |
| ME 345 | Fluid Power (3) |
| ME 348 | Computer-Aided Design (3) |
| ME 360 | Nuclear Reactor Engineering (3) |

Any design or manufacturing course taken outside of Mechanical Engineering must be approved by the student's advisor.

Other approved elective courses in the Mechanical Engineering and Mechanics Department are:

| | |
|---|---|
| ME 320 | Thermodynamics III (3) |
| Mech 307 | Mechanics of Continua (3) |
| Mech 312 | Finite Element Analysis (3) |
| Mech 313 | Fracture Mechanics (3) |
| Mech 323 | Fluid Mechanics of Ocean and Atmosphere (3) |
| Mech 326 | Aerodynamics (3) |

## Undergraduate Courses in Mechanical Engineering

**ME 10. Graphics for Engineering Design (4)** fall
Engineering graphics, elements of descriptive geometry, and geometric aspects of design including their interaction with manufacturing. Emphasis on computer graphics and computer-aided design and manufacturing (CAD/CAM) methods.

**ME 21. Mechanical Engineering Laboratory I (1)** fall, spring
Laboratory methods employed in mechanical engineering and mechanics. Planning and execution of experiments, analysis of data, and writing of reports. Introduction to elementary instrumentation. Prerequisite: Mech 11, previously or concurrently.

**ME 101. Mechanical Engineering Design I (2)** spring
Objectives and specifications are developed for design projects to be carried out in the following semester. Alternative design concepts are proposed and oral and written reports of feasibility studies are presented.

**ME 102. Mechanical Engineering Design II (2)** fall
A continuation of ME 101 in which groups are organized to do preliminary design on a previously defined project. Program organization techniques are used and laboratory testing and data acquisition are carried out as needed to promote design development. Prototypes are constructed and tested, when practical. Prerequisites: ME 101, Mech 11, and ME 104.

**ME 104. Thermodynamics I (3)** fall, spring
Basic concepts and principles of thermodynamics with emphasis on simple compressible substances. First and second law development, energy equations, reversibility, entropy and probability. Properties

of pure substances and thermodynamic cycles. Prerequisites: Math 23 and Phys 11.

**ME 105. Thermodynamics II (3)** fall, spring
Equations of state, nonreacting and reacting mixtures, combustion, equilibrium of mixtures both reacting and nonreacting, statistical thermodynamics concepts. Prerequisite: ME 104.

**ME 108. Mechanical Engineering Laboratory III (2)** fall
Lectures and laboratory exercises relating to various phases of engineering laboratory technique and procedures. Includes planning, execution, and analysis of tests and writing of reports. Prerequisite: ME 105.

**ME 109. Mechanical Engineering Laboratory IV (2)** spring
Continuation of ME 108.

**ME 110. Thesis (1-2)** fall-spring
Candidates for the degree of bachelor of science in mechanical engineering may, with the approval of the director of the curriculum, undertake a thesis as a portion of the work during the senior year.

**ME 121. Mechanical Engineering Laboratory II (1)** fall, spring
A continuation of ME 21 including the use of transducers, advanced instrumentation, and data acquisition. Emphasis on the planning of experiments and interpretation of results. Prerequisites: ME 21 and ME 104.

**ME 151. Mechanical Elements (3)** fall, spring
Methods for the analysis and design of machine elements such as springs, gears, clutches, brakes, and bearings. Motion analysis of cams and selected mechanisms. Projects requiring the design of simple mechanisms of mechanical sub-assemblies. Prerequisites: Mech 11, ME 10 and Mech 102.

## For Advanced Undergraduates and Graduate Students

**ME 231. Fluid Mechanics (3)** fall, spring
Fundamental concepts. Physical similarity. Kinematics of fluid flow. Equations of flow in integral form. Equations of flow of perfect fluids. Plane irrotational flow of incompressible fluids. Navier-Stokes equation: hydrodynamic stability; turbulence. Two-dimensional boundary layers in incompressible flows: separation of flow; wakes; drag. Effects of compressibility of fluid flow. Hydraulic treatment of losses in flows in ducts. Flows with free surface. Basic measurements techniques. Prerequisite: Math 205.

**ME 242. Mechanical Vibrations (3)** fall, spring
Physical modeling of vibrating systems. Linearization. Free and forced single and multiple degree of freedom systems. Simple continuous systems. Engineering applications. Prerequisites: Mech 11, Mech 102 or 103, Math 205.

**ME 310. Projects (1-3)** fall, spring
Project work on any aspect of engineering, performed either individually or as a member of a team made up of students, possibly from other disciplines. Direction of the projects may be provided by faculty from several departments and could include interaction with outside consultants and local communities and industries. Prerequisite: consent of the department chairperson.

**ME 312. Synthesis of Mechanisms (3)** fall
Geometry and constrained plane motion with application to linkage design. Type of number synthesis. Comparison of motion analysis by graphical, analytical and computer techniques. Euler-Savary and related curvature techniques as applied to cam, gear and linkage systems. Introduction to the analysis of space mechanisms. Prerequisites: Math 205, Mech 102. Terry

**ME 320. Thermodynamics III (3)** fall
Advanced treatment of thermodynamic laws both for single element and mixtures. Phase equilibrium. Ideal solutions, chemical equilibrium. Thermodynamic cycle analysis, real fluid properties, availability. Prerequisite: ME 104. Macpherson

**ME 321. Introduction to Heat Transfer (3)** fall, spring
Analytical, numerical, and analog solutions to steady and transient, one- and two-dimensional conduction problems; thermal radiation, free and forced convection of laminar and turbulent flows inside cylindrical tubes and over external surfaces; thermal design of heat. Prerequisites: ME 104, ME 231. Levy, Neti, Walker

**ME 322. Gas Dynamics (3)** spring
Equations of flow of compressible fluids. Thermodynamic properties of gases. Shock waves. One-dimensional steady flow through ducts with variable cross-sectional area, flows with viscous friction and heat addition. Prerequisites: ME 231, ME 104, Math 205. Owczarek, Rockwell

**ME 323. Reciprocating and Centrifugal Engines (3)** fall
Thermal analysis and design of internal combustion engines (conventional and unconventional), gas turbine engines, air breathing jet engines, and rockets. Components such as jet nozzles, compressors, turbines, and combustion chambers are chosen to exemplify the theory and development of different types of components. Both ideal fluid and real fluid approaches are considered. Prerequisite: ME 105.

**ME 327. Coal Combustion and Conversion (3)** fall
Application of the thermal-fluid sciences in the analysis and critical assessment of coal combustion and conversion processes. Properties of coal; environmental constraints; precombustion cleaning; fluidized bed combustion; flue gas desulfurization; gasification; liquefaction; power cycle analysis; energy economics. Prerequisite: ME 105 or senior standing. Levy

**ME 329. Solar Energy Conversion (3)** fall
Modeling of flat plate, concentrating, imaging and non-imaging collectors. Estimation of available solar energy. Physics of solar cells. Storage systems. Solar heating design. Engineering economics as applied to solar system design. Passive system analysis and design. Prerequisite: a first course in thermodynamics. Neti, Sarubbi

**ME 331. Advanced Fluid Mechanics (3)** fall
Kinematics of fluid flow. Conservation equations for inviscid and viscous flows; integral forms of equations. Two-dimensional potential flow theory of incompressible fluids with applications. Boundary layers. Introduction to free shear layer and boundary layer stability and structure of turbulence. Transition from laminar to turbulent boundary layers. Separation of flow. Steady and unsteady stall. Secondary flows. Flow of non-Newtonian fluids. Hydrodynamic lubrication. Measurement techniques. Prerequisite: ME 231 or equivalent. Owczarek, Rockwell, C. Smith

**ME 340. Advanced Mechanical Design (3)** fall
Probabilistic design of mechanical components and systems. Reliability functions, hazard models and product life prediction. Theoretical stress-strength-time models. Static and dynamic reliability models. Optimum design of mechanical systems for reliability objectives or constraints. Prerequisite: Math 231. Benner

**ME 341. Mechanical Systems (3)** spring
Advanced topics in mechanical systems design. Friction, wear and lubrication with applications of friction drives, journal and rolling-element bearings. Shock and vibration control in machine elements such as springs, gears and rotating discs. Rotor-bearing system dynamics. Balancing of rotating and reciprocating machines. Prerequisites: ME 151, Mech 203 and ME 242. Benner, Lucas

**ME 342. Dynamics of Engineering Systems (3)** spring
Dynamic analysis of mechanical, electromechanical, fluid and thermal engineering systems with emphasis on the modeling process. Survey of numerical methods with emphasis on dynamic simulation and computer practice. Prerequisite: ME 242. Johnson

**ME 343. Control Systems (3)** fall

Linear analysis of mechanical, hydraulic, pneumatic, thermal and electrical feedback control systems. Transient and frequency response, root locus, stability criteria and compensation techniques. Prerequisite: ME 242. Brown, Johnson

**ME 345. Fluid Power (3)** fall

Design, modeling and static and dynamic analyses of fluid power pumps, motors, valves, lines and systems, with emphasis on developing a fundamental understanding of industrial and mobile hydraulics and hydraulic servosystems. Laboratory demonstrations and experiments. Prerequisites: ME 231 and, previously or concurrently, ME 242. Brown

**ME 348. Computer-Aided Design (3)** spring

Impact of computer graphics technology on mechanical design and manufacturing. Geometric modeling including wireframe modeling, solids modeling, computer graphics and CAD/CAM systems. Analysis techniques for mass properties, kinematics and the use of finite elements for distributed properties. Design for manufacturability and automated assembly. Prerequisites: ME 10, ME 151, ME 242. Ochs, Lucas

**ME 350. Special Topics (1-4)**

A study of some field of mechanical engineering not covered elsewhere. Prerequisite: consent of the department chairperson.

**ME 360. (ChE 360) Nuclear Reactor Engineering (3)** spring

A consideration of the engineering problems in nuclear reactor design and operation. Topics include reactor fuels and materials, thermal aspects, instrumentation and control problems, radiation protection and shielding, fuel processing, and reactor design. Prerequisite: senior standing in engineering or physical science. Neti, Chen

**ME 387. (ChE 387, ECE 387) Digital Control (3)** spring

Sampled-data systems; z-transforms; pulse transfer functions; stability in the z-plane; root locus and frequency response design methods; minimal prototype design; digital control hardware; discrete state variables; state transition matrix; Liapunov stability state feedback control (2 lectures and one laboratory per week). Prerequisite: ChE 386 or ECE 212 or ME 342 or consent of instructor. Luyben

## Graduate Programs in Mechanical Engineering

The department offers programs of study leading to the degrees of master of science, master of engineering, and doctor of philosophy in mechanical engineering.

A student whose background is different from that required in the undergraduate mechanical engineering curriculum or who has a particular deficiency may be required to present a larger number of credits than the minimum indicated for graduation.

Subject to approval, courses from other engineering curricula, such as mechanics, chemical engineering, and metallurgy and materials engineering, may be included in the major.

A student who plans to work for the doctorate should submit a general plan to the department chairperson during the first year and arrange for the qualifying examinations.

### *Master of Science*

The M.S. degree is often considered the appropriate background for the person who wants to work on the more technical creative aspects of mechanical engineering. As such it emphasizes a broad extension of fundamentals rather than specialization in one field, although there is considerable latitude in the choice of courses.The required six-credit-hour thesis for the M.S. would likely concentrate in one research area.

### *Master of Engineering*

The program leading to the M.Eng. degree aims primarily at advanced design methods and creative design projects. Six credit hours of ME 460, Engineering Project, are required in lieu of a thesis. A wide range of interdisciplinary course offerings permits construction of a program including several of the following areas: mechanical systems, reliability engineering, probabilistic approaches to design, mechanism synthesis, stress analysis, digital and analog computer-aided design, and optimum design.

### *Doctor of Philosophy*

Candidacy for the Ph.D. degree follows passing the qualifying examination that also emphasizes a broad grasp of fundamentals. In most cases, largely through the dissertation, the candidate emphasizes one or more specialized fields and engages in extensive research in collaboration with one or more faculty members. Basic and applied research is ongoing in a variety of fields including fluid and solid mechanics, heat and mass transfer, thermodynamics, energy conversion, mechanical design and system dynamics and control.

Equipment available for research includes mini- and micro-computers with A/D converters, high-speed TV and photographic system, several channels of hot wire/film anemometry, a six-inch interferometer, a two-phase boiling loop, several water and wind tunnels, fluidized bed test facilities, a fluidized combustor, gas-dynamic test facilities, a corrosion fatigue test facility, a variety of electrodynamics and servo-controlled hydraulic testing machines, a 1200-pound shaker table, a photo-elastic bench, lasers, and fluid power test stands. The Computer-Aided Design (CAD) Laboratory includes 5 DEC Mini-Computers that support 32 graphics terminals. Commercial software is available for design, testing, analysis and solids modeling.

Some of the recent research activities of the staff are listed below.

**Thermofluids.** Structure of turbulent boundary layers, wakes and jets; drag reduction in turbulent flows; acoustic-flow interactions; attenuation of aerodynamic noise; flows in radial compressors; vortex-solid boundary interactions, flow in gas centrifuges; unsteady viscous flows; viscous effects in turbomachinery; rotating fluidized beds; fluidized bed combustion; instrumentation for liquid film dynamics; inverse annular two-phase flows; laminar/turbulent transaction behind a barrier; self-sustained oscillations of separated flows; flow-induced vibrations; fluid transients in tubes; Laser-Doppler velocimetry; fluidized-bed heat exchangers; multi-component boiling; convection in postcritical heat-flux boiling; thermal hydraulics of liquid metal boiling; Raman spectra applied to temperatures in two-phase flow; measurements in gas flows following shock waves; optimization of designs of air separation plants; cycle analysis for fluidized-bed combustors; cycle analysis applied to coal gasifiers and powercycles; breeder-reactor safety; light-water reactor safety; control optimization of heat pumps; finite element computations relative to turbulent flows; flutter of blades in axial-flow turbomachinery.

**System dynamics and control.** Modeling and advanced simulation of dynamic systems including vehicles, chemical processes, aero-elastic structures and heat-pump systems; methods of experimental identification and analysis of distributed-parameter systems including unsteady turbulent flow in tubes and diffusers; energy methods and bondgraphs in modeling; stochastic optimal control techniques applied to stable platforms for overland vehicles; conceptualization and hardware development of innovative components and systems for fluid power control; application of robots to manufacturing; computer-controlled theatre lighting design.

Except for the core courses, graduate courses are generally offered every third semester.

**ME 411. Boundary-Layer Theory (3)** fall

The course is intended as a first graduate course in viscous flow. An introduction to boundary-layer theory, thermodynamics and heat transfer at the undergraduate level are assumed to have been

completed. Topics include the fundamental equation of continuum fluid mechanics, the concept of asymptotic methods and low and high Reynolds number flows, laminar boundary layers, generalized similarity methods, two- and three-dimensional flows, steady and unsteady flows and an introduction to hydrodynamic stability. The material is covered in the context of providing a logical basis as an introduction to a further course in turbulent flows. Walker

**ME 413. Numerical Methods in Mechanical Engineering (3)**
Zeros of functions, difference tables, interpolation, integration, differentiation. Divided differences, numerical solution of ordinary differential equations of the boundary and initial value type. Eigen problems. Curve fitting, matrix manipulation and solution of linear algebraic equations. Partial differential equations of the hyperbolic, elliptic and parabolic type. Application to problems in mechanical engineering. Walker

**ME 415. Flow-Induced Vibrations (3)**
Excitation of streamlined- and bluff-bodies by self-flutter, vortex, turbulence, and gust-excitation mechanisms. Analogous excitation of fluid (compressible- and free-surface) systems having rigid boundaries. Extensive case studies. Rockwell

**ME 420. Advanced Thermodynamics (3)** spring
Critical review of thermodynamics systems. Criteria for equilibrium. Applications to electromagnetic systems. Statistical thermodynamics. Irreversible thermodynamics. Thermoelectric phenomena. Macpherson

**ME 421. Topics in Thermodynamics (3)**
Emphasis on theoretical and experimental treatment of combustion processes including dissociation, flame temperature calculations, diffusion flames, stability and propagation; related problems in compressible flow involving one-dimensional, oblique shock waves and detonation waves. Methods of measurement and instrumentation. Staff

**ME 424. Turbulent Flow (3)** fall
Stability of laminar flow; transition to turbulence. Navier-Stokes equations with turbulence. Bounded turbulent shear flows; free shear flows; statistical description of turbulence. Prerequisite: ME 331. Rockwell

**ME 426. Radiative and Conductive Heat Transfer (3)** spring
Principles of radiative transfer; thermal-radiative properties of diffuse and specular surfaces; radiative exchange between bodies; radiative transport through absorbing, emitting and scattering media. Advanced topics in steady-state and transient conduction; analytical and numberical solutions; problems of combined conductive and radiative heat transfer. Prerequisite: ME 321 or ChE 421. Staff

**ME 427. (ChE 427) Multiphase Heat Transfer (3)**
Heat transfer and fluid dynamics of multiphase systems. Subcooled, nucleate, and film boiling; bubble nucleation; dynamics of bubble growth and collapse; vapor-liquid cocurrent flow regimes; two-phase pressure drop and momentum exchange, low instabilities; convective-flow boiling; simultaneous heat and mass transfer. Prerequisite: ME 321 or ChE 421. Staff

**ME 428. Boundary Layers and Convective Heat Transfer (3)** spring
Navier-Stokes and energy equations, laminar boundary layer theory, analysis of friction drag, transfer and separation. Transition from laminar to turbulent flow. Turbulent boundary layer theory. Prandtl mixing length, turbulent friction drag, and heat transfer. Integral methods. Flow in ducts, wakes and jets. Natural convection heat transfer. Prerequisite: ME 331 or ME 321. Levy, Owczarek, Rockwell

**ME 431. Advanced Gas Dynamics (3)**
Method of characteristics. Unsteady continuous flow. Unsteady flows with discontinuities. Shock tubes. Detonation waves. Two-dimensional and axisymmetric supersonic flows. Momentum and energy equation of compressible viscous fluids. Prerequisite: ME 322. Owczarek, Rockwell

**ME 432. Topics in Gas Dynamics (3)**
The equilibrium thermodynamic properties of a dissociating mixture of gases. Equilibrium flow of dissociating gases. Vibrational and chemical nonequilibrium. Criteria for thermodynamic equilibrium of gas flow. Chemical kinetics of gaseous reactions. Equations of flow of a reacting gas mixture. Nonequilibrium flows. Application to design of ram-jets and rocket nozzles and of reentry vehicles. Prerequisite: ME 320 and ME 322. Staff

**ME 433. (ChE 433, ECE 433) State Space Control (3)**
State-space methods of feedback control system design and design optimization for invariant and time-varying deterministic, continuous systems; pole positioning, observability, controllability, modal control, observer design, the theory of optimal processes and Pontryagin's Maximum principle, the linear quadratic optimal regulator problem, Lyapunov functions and stability theorems, linear optimal openloop control; introduction to the calculus of variations; introduction to the control of distributed parameter systems. Intended for engineers with a variety of backgrounds. Examples will be drawn from mechanical, electrical and chemical engineering applications. Prerequisite: ME 343 or ECE 212 or ChE 386 or consent of instructor. Johnson, Georgakis

**ME 434. (ChE 434, ECE 434) Multivariable Process Control (3)**
A state-of-the-art review of multivariable methods of interest to process control applications. Design techniques examined include loop interaction analysis, frequency domain methods (Inverse Nyquist Array, Characteristic Loci and Singular Value Decomposition) feedforward control, internal model control and dynamic matrix control. Special attention is placed on the interaction of process design and process control. Most of the above methods are used to compare the relative performance of intensive and extensive variable control structures. Prerequisite: ChE 433 or ME 433 or ECE 433 or consent of instructor. Georgakis

**ME 436. (ChE 436, ECE 436) Systems Identification (3)**
The determination of model parameters from time-history and frequency response data by graphical, deterministic and stochastic methods. Examples and exercises taken from process industries, communications and aerospace testing. Regression, quasilinearization and invariant-imbedding techniques for nonlinear system parameter identification included. Prerequisite: ChE 433 or ME 433 or ECE 433 or consent of instructor. Johnson

**ME 437. (ChE 437, ECE 437) Stochastic Control (3)**
Linear and nonlinear models for stochastic systems. Controllability and observability. Minimum variance state estimation. Linear quadratic Gausian control problem. Computational considerations. Nonlinear control problem in stochastic systems. Prerequisite: ChE 433 or ME 433 or ECE 433 or consent of instructor. Staff

**ME 439. Fluid Mechanics of Turbo-machinery (3)**
The Euler equation. One-dimensional analysis of turbomachinery. Performance characteristics. Limitations on performance imposed by real fluid effects. Cascade flow. Two- and three- dimensional flow. Surge and stall. Owczarek

**ME 442. Analytical Methods in Engineering I (3)** fall
Analytical methods of solution for discrete and continuous engineering systems. Theoretical, numerical and approximate methods of solution applied to equilibrium, characteristic value and propagation types of engineering problems. Lucas, Walker, Erdogan, Sawyers

**ME 443. Analytical Methods in Engineering II (3)** spring
Continuation of ME 442.

**ME 444. Experimental Stress Analysis in Design (3)**
Fundamental concepts of strain measurements and application of strain gages and strain gage circuits. Two- and three-dimensional photoelasticity, stress separation techniques, birefringent coating Moire methods, caustics. Use of image analysis in data acquisition and interpretation. Selected laboratory experiments. Voloshin

**ME 446. Mechanical Reliability (3)**
Design of mechanical engineering systems to reliability specifications. Probabilistic failure models for mechanical

components. Methods for the analysis and improvement of system reliability. Effect of component tolerance and parameter variation on system failure. Reliability testing. Prerequisite: Math 231 or Math 309. Benner

**ME 450. Special Topics (3)**
An intensive study of some field of mechanical engineering not covered in more general courses.

**ME 451. Seminar (1-3)**
Critical discussion of recent advances in mechanical engineering.

**ME 458. Modeling of Dynamic Systems (3)**
Modeling of complex linear and nonlinear energetic dynamic engineering systems. Emphasis on subdivision into multiport elements and representation by the bondgraph language using direct, energetic, and experimental methods. Field lumping. Analytical and graphical reductions. Analog, digital and hybrid simulation. Examples including mechanisms, electromechanical transducers, electric and fluid circuits, and thermal systems. Prerequisite: ME 342 or ME 343 or ECE 212. Brown, Johnson

**ME 460. Engineering Project (1-6)**
Project work on some aspect of mechanical engineering in an area of student and faculty interest. Selection and direction of the project could involve interaction with local communities or industries. Prerequisite: consent of the department chairperson.

## B.S. in Engineering Mechanics

The curriculum in Engineering Mechanics is designed to prepare students for careers in engineering research and development and is especially appropriate for students wishing to specialize in the analysis of engineering systems. In many industries and governmental laboratories there is a certain demand for men and women with broad training in the fundamentals of engineering in which engineering mechanics and applied mathematics play an important part.

The first two years of the curriculum is the same as that in Mechanical Engineering. One of the advantages of the curriculum is the flexibility it offers through 18 credits of technical and 6 credits of personal electives in the junior and senior years. Beyond the sophomore year there are required courses in dynamics, solid mechanics, fluid mechanics, heat transfer, principles of electrical engineering, mathematics, vibrations, and senior laboratories or projects. It is recommended that the electives be chose neither to concentrate on areas such as applied mathematics and computational mechanics, solid mechanics, engineering materials, and fluid mechanics or to obtain further depth in all areas. Each student must select a minimum of 12 credits from the courses listed under options and six additional credits of approved technical electives from this list or from other courses offered in the departments of mathematics, physics or chemistry, or in the college of engineering and applied science. The academic advisor for the Engineering Mechanics program will provide guidance in formulating the student's goals and choosing the electives.

In addition to the required and elective courses in mathematics, sciences and engineering, the B.S. degree program in Engineering Mechanics includes 25 credits of general studies (page 37). The total graduation requirements is 131 credits.

## Undergraduate Curriculum in Engineering Mechanics

**freshman and sophomore years:** same as ME curriculum

**junior year, first semester** (17 credit hours)

| | |
|---|---|
| Mech 102 | Dynamics (3) |
| ME 231 | Fluid Mechanics (3) |
| ME 121 | Mechanical Engineering Laboratory II (1) |
| ECE 81 | Principles of Electrical Engineering (4) |
| Mech 203 | Advanced Strength of Materials (3) |
| | general study elective (3) |

**junior year, second semester** (16 credit hours)

| | |
|---|---|
| ECE 162 | Electrical Laboratory (1) |
| ME 242 | Mechanical Vibrations (3) |
| Math 208 | Complex Variables (3) |
| Math 230 | Numerical Methods (3) |
| | general study elective (3) |
| | Engineering Mechanics elective (3) |

**senior year, first semester** (17 credit hours)

| | |
|---|---|
| ME 321 | Introduction to Heat Transfer (3) (or equivalent) |
| ME 108 | Mechanical engineering Laboratory III (2) **or** |
| ME 110 | Thesis (2) |
| | free elective (3) |
| | general study elective (3) |
| | Engineering Mechanics electives (6) |

**senior year, second semester** (17 credit hours)

| | |
|---|---|
| ME 109 | Mechanical Engineering Laboratory IV (2) **or** |
| ME 110 | Thesis (2) |
| | general study elective (3) |
| | free elective (3) |
| | Engineering Mechanics electives (9) |

Total credits for graduation: 131

Typical recommended options

**Applied Mathematics and Computational Mechanics**

| | |
|---|---|
| Math 322 | Methods of Applied Analysis I (3) |
| Math 323 | Methods of Applied Analysis II (3) |
| Mech 305 | Advanced Mechanics of Materials (3) |
| Mech 312 | Finite Element Analysis (3) |
| Math 309 | Theory of Probability (3) |

**Solid Mechanics**

| | |
|---|---|
| Math 322 | Methods of Applied Analysis I (3) |
| Mech 305 | Advanced Mechanics of Materials (3) |
| Mech 312 | Finite Element Analysis (3) |
| Mech 313 | Fracture Mechanics (3) |
| Mech 307 | Mechanics of Continua (3) |

**Engineering Materials**

| | |
|---|---|
| Phys 31 | Introduction to Quantum Mechanics (3) |
| Mat 218 | Mechanical Behavior of Materials (3) |
| Phys 363 | Physics of Solids (3) |
| Mech 305 | Advanced Mechanics of Materials (3) |

**Fluid Mechanics**

| | |
|---|---|
| Math 322 | Methods of Applied Analysis I (3) |
| ME 331 | Advanced Fluid Mechanics (3) |
| ME 322 | Gas Dynamics (3) |
| Mech 326 | Aerodynamics (3) |

## Undergraduate Courses in Engineering Mechanics

**Mech 1. Statics (3)** fall-spring
Composition and resolution of forces; equivalent force systems; equilibrium of particles and rigid bodies; centroids and centers of gravity; analysis of simple structures; internal forces in beams; friction; moments and products of inertia; methods of virtual work. Prerequisites: Math 22 and Phys 11.

**Mech 11. Mechanics of Materials (3)** fall-spring
Strength and elasticity of materials; theory of stresses and strains; deflection of beams and shafts; torsion; buckling of struts. Prerequisites: Mech 1, Math 23, previously or concurrently.

**Mech 102. Dynamics (3)** fall-spring
Kinematics and kinetics of particles and rigid bodies in two and three

dimensions; relative motion; work and energy; impulse and momentum. Prerequisites: Mech 1 and Math 23.

**Mech 103. Principles of Mechanics (4)**
Composition and resolution of forces; equivalent force systems; equilibrium of particles and rigid bodies; friction. Kinematics and kinetics of particles and rigid bodies; relative motion; work and energy; impulse and momentum. Prerequisites: Math 23 and Phys 11.

## For Advanced Undergraduates and Graduate Students

**Mech 203. Advanced Strength of Materials (3)** fall-spring
Elementary consideration of stress and strain at a point. Stress strain relation in two dimensions. Basic equations of motion. Classical theories of failures. Analysis of simple continuum systems with applications to materials behavior phenomena. Prerequisites: Mech 11 and Math 205.

**Mech 302. Advanced Dynamics (3)** spring
Fundamental dynamic theorems and their application to the study of the motion of particles and rigid bodies, with particular emphasis on three-dimensional motion. Use of generalized coordinates; Lagrange's equations and their applications. Prerequisites: Mech 102 or 103; Math 205. Sarubbi, Johnson

**Mech 305. Advanced Mechanics of Materials (3)** fall
Selected problems of stress and strain that are governed by ordinary differential equations such as combined bending and torsion of bars, curved bars, beams and elastic foundation. Membrane analogy. Principles of indeterminate analysis. Energy methods. Prerequisites: Mech 203 or equivalent; Math 205.

**Mech 307. Mechanics of Continua (3)** spring
Fundamental principles of the mechanics of deformable bodies. Study of stress, velocity and acceleration fields. Compatibility equations, conservation laws. Applications to two-dimensional problems in the theories of perfectly elastic materials and also perfectly plastic materials. Prerequisites: Mech 203 and 305. Varley

**Mech 312. Finite Element Analysis (3)** spring
Basic concepts for representing distributed-parameter media with complicated boundaries by a system of small elements. Emphasis on elastic media. Element stiffness matrices based on assumed displacements. Isoparametric elements. Assembly of global stiffness matrix. Applications to plane elasticity, solids of revolution, bending of plates, shells, vibration, and heat transfer. Students use prewritten Fortran subroutines to produce their own finite element program. Prerequisites: Mech 11 and Math 205. Kalnins

**Mech 313. Fracture Mechanics (3)** spring
Fracture behavior in solids, the Griffith theory and extensions to linear elastic fracture process models; stress analysis of cracks; generalization of fracture criteria; plasticity; subcritical crack growth, including environmental and thermal effects; fracture toughness testing; failure analysis and fracture control plans. Prerequisites: Mech 11 and Math 205. Roberts, Sih, Wei

**Mech 323. (CE 324) Fluid Mechanics of Ocean and Atmosphere (3)** fall
Hydrostatics of the ocean and atmosphere. Vertical stability. Fluid motion in a rotating cordinate system. Geostrophic flow; ocean currents; surface and internal waves. Prerequisite: ME 231 or CE 121. Macpherson

**Mech 326. Aerodynamics (3)** spring
Application of fluid dynamics to external flows. Simple exact solutions in two dimensions. Kutta condition at a trailing edge. Thin aerofoil theory, steady and unsteady flow. Lifting line theory. Flow past slender bodies. Linearized compressible flow. Far field solutions, shock formation. Prerequisites: ME 231 and Math 208. Blythe

**Mech 350. Special Topics (3)**
A study of some field of engineering mechanics not covered elsewhere. Prerequisite: consent of the department chairperson.

## Graduate Program in Engineering Mechanics

Graduate courses in engineering mechanics are open in general to students who have been graduated from a curriculum in engineering mechanics, engineering mathematics, engineering physics, civil engineering, or mechanical engineering at a recognized institution. Graduate degrees are given in *Applied Mechanics*.

A candidate for the M.S. in applied mechanics is expected to possess a thorough knowledge of undergraduate mathematics and mechanics. Math 205, 208 and 322, and Mech 302 and 305, or their equivalents, are considered prerequisites for graduate work in applied mechanics. Any of these courses that have not been taken by the student as an undergraduate should be included in the graduate program. The student may then be required to present a larger number of credits than the minimum required for graduation. A thesis carrying six credit hours is required of all M.S. candidates.

Current departmental research activities of interest include programs as follows:

**Continuum mechanics.** Formulation of field equations and constitutive equations in non-linear elasticity theories. Mechanics of viscoelastic solids and fluids, plasticity theory. Generalized continuum mechanics. Thermomechanical and electro-mechanical interactions. Stress birefringence. Wave propagation. Finite amplitude wave propagation.

**Fracture mechanics.** Stress analysis of materials containing defects, including viscoelastic, non-homogeneous, and anisotropic materials. Analysis of crack growth under static, periodic, and random loadings and environmental effects. Optimizations of fracture control. Crack propagation theories for nonlinear materials. Influence of cracks on the strength of structural members and of interfaces. Applications to composites, structural and microelectronic components.

**Stochastic processes.** Modeling of random behavior in mechanical systems. Static and time-dependent stochastic fracture mechanics.

**Thin shell analysis.** Free vibration and dynamic response of elastic shells. Elastic-plastic deformations of shells upon cyclic thermal loadings. Applications of shell analysis to nuclear power plant components (pressure vessels, curved pipes), and to biological systems (eye, frog's eggs and other cells).

**Theoretical fluid mechanics.** Vortex boundary layer interaction, modeling of turbulent boundary layers; geophysical flows such as frontal systems and mountain flows; statistical mechanics of plasmas, liquids and shock waves; finite amplitude waves in stratified gases and liquids; shock wave propagation; non-Newtonian flows in flexible tubes with application to hemorheology; magneto-fluid mechanics; wing theory; thermally driven flows.

Special departmental facilities of interest to the graduate student include the latest mechanical, electrodynamic and servocontrolled hydraulic testing machines, photoelastic bench, laser, and corrosion fatigue test facilities.

Except for the core courses graduate courses are generally offered every third semester.

**Mech 402. Advanced Analytical Mechanics (3)** fall
Fundamental dynamical theorems and their applications to advanced problems; generalized coordinate; Lagrange's equations; fixed and moving constraints; nonholonomic systems; Hamilton's principle; Hamilton's canonical equations; contact transformations; Hamilton-Jacobi partial differential equation. Prerequisite: Mech 302 or consent of the department chairperson. Johnson, Sarubbi

**Mech 405. Response of Systems to Random Loads (3)** fall
Stochastic processes; correlation functions and power spectra; response of mechanical systems to one-dimensional and multidimensional random load fields; probability of the random vibrations of mechanical systems; applications to failure prediction. Prerequisite: consent of the department chairperson. Harlow, Sarubbi

**Mech 406. Advanced Dynamics and Vibrations (3)** fall
Kinematical and mathematical preliminaries, basic notions of variational calculus; Hamilton's principle. Lagrange equations,

discrete systems; dynamics of continuous systems. Sturm-Liouville theory, eigenvalue problems; transient and frequency response. There will be frequent examples of the application of these techniques to the analysis of shafts, beams, membranes, and plates. Prerequisites: ME 242 and Mech 302. Erdogan, S. Johnson

**Mech 407. Wave Propagation in Solids (3)** fall
Wave propagation in deformable elastic solids; problems in half-space and layered media; application of integral transformations. Erdogan, Delph, Varley

**Mech 409. Theory of Elasticity II (3)** fall
Kinematics of deformation, analysis of stress, stress-strain relations, strain energy function. Reciprocal theorem. Methods for two-dimensional boundary value problems applied to anti-plane, torsion, bending and plane problems. Approximate and numerical methods of solution. Prerequisites: Math 205; Mech 305 or equivalent course in advanced mechanics of material. Erdogan, Hartranft, Sih

**Mech 410. Theory of Elasticity II (3)** spring
Advanced topics in the theory of elasticity. The subject matter may vary from year to year and may include, e.g., theory of potential functions, linear thermoelasticity, dynamics of deformable media, integral transforms and complex-variable methods in classical elasticity. Problems of boundary layer type in elasticity; current developments on the micro-structure theory of elasticity. Prerequisites: Mech 409, Math 208, or consent of the department chairperson. Erdogan, Sih

**Mech 411. (Phys 471) Continuum Mechanics (3)**
An introduction to the continuum theories of the mechanics of solids and fluids. This includes a discussion of the mechanical and thermodynamical bases of the subject, as well as the use of invariance principles in formulating constitutive equations. Applications of the theories to specific problems are given. G. Smith

**Mech 412. Theory of Plasticity (3)**
Time-independent mechanical behavior in simple tension, compression and torsion. Time-independent stress-strain relations for materials under combined stress. Application to problems with axisymmetric stress distributions. Loading, unloading, residual stresses, shakedown. Limit theorems of perfectly plastic bodies; applications. The slip line field for plane strain; examples. Plastic analysis of structures; frames, plates, shells. Finite element approach to problems. Time-dependent mechanical behavior of materials, creep. Prerequisites: Math 205; Mech 305 or equivalent course in advanced mechanics of materials. Kalnins, Updike

**Mech 413. Fracture Mechanics (3)**
Introduction to fracture mechanics criteria for bodies containing cracks and notches; microscopic and macroscopic analytical modeling; fracture toughness concept; test specimens; stress intensity factor evaluation of crack systems; prediction of crack trajectory and direction of initiation; dynamic loading and crack propagation; fatigue crack growth and environmental effects; brittle-ductile transition phenomenon in metals; visco-elastic behavior of polymers. Prerequisites: Mech 203, Math 208, or consent of the department chairperson. Erdogan, Sih, Wei

**Mech 414. Viscoelasticity and Creep (3)**
Mechanical models for linear viscoelastic materials, representations by differential operators and hereditary integrals, creep and relaxation functions, correspondence principle, quasi-static analysis, wave propagation, nonlinear material behavior, uniaxial creep laws, multiaxial generalizations, creep damage and failure. Prerequisite: Mech 409. Delph

**Mech 415. (CE 468) Stability of Elastic Structures (3)**
Basic concepts of instability of a structure; bifurcation, energy increment, snap-through, dynamic instability. Analytical and numerical methods of finding buckling loads of columns. Postbuckling deformations of cantilevel column. Dynamic buckling with nonconservative forces. Effects of initial imperfections. Inelastic buckling. Buckling by torsion and flexure. Variational methods. Buckling of frames. Instability problems of thin plates and shells. Prerequisite: Math 205. Kalnins

**Mech 416. (CE 464) Analysis of Plates and Shells (3)** fall
Bending of rectangular and circular plates, plates under lateral loads, plates with thermal and inelastic strains, effect of inplane forces, large deflections, buckling of plates. Geometry and governing equations of shell, shells of revolution, membrane states, edge solutions, solution by numerical integration, non-symmetric problems, buckling of shells, applications to pressure vessels. Prerequisites: Math; Mech 305, or equivalent course in advanced mechanics of materials. Kalnins, Updike

**Mech 417. Mixed Boundary Value Problems in Mechanics (3)**
General description of mixed boundary value problems in potential theory and solid mechanics. Solutions by dual series, dual integral equations and singular integral equations. Approximate and numerical methods. Erdogan

**Mech 418. Finite Element Methods (3)** fall
Finite element approximations to the solutions of differential equations of engineering interest are developed from variational principles or by Galerkin's method. Linear and nonlinear example from heat transfer, solid mechanics, and fluid mechanics are used to illustrate applications of the method. The course emphasizes the development of computer programs to carry out the required calculations. Prerequisite: knowledge of FORTRAN. Delph

**Mech 419. (ChE 419) Asymptotic Methods in the Engineering Sciences (3)**
Introductory level course with emphasis on practical applications. Material covered includes: Asymptotic expansions. Regular and singular perturbations; asymptotic matching. Boundary value problems; distinguished limits. Multiple scale expansion. W.K.B. Theory. Far field theories. Blythe

**Mech 421. Fluid Mechanics (3)**
Kinematics of fluid flow. Lagrangian and Eulerian descriptions. Basic conservation laws. Review of thermodynamics. Constitutive relations. Vorticity, circulation. Irrotational flow. Bernoulli theorems. Vortex motion, velocity motion, velocity potential, stream function. Potential flow in two and three dimensions. Compressible flow; sound waves, simple waves; gas dynamic discontinuities. Salathe, Blythe

**Mech 422. Fluid Mechanics (3)**
Similarity and dimensional analysis. Exact solution for viscous incompressible flow. Singular perturbation theory, with application to flows at low and high Reynolds number. Hydrodynamic stability. Depending on interest, additional topics from Magnetohydrodynamics, kinetic theory, wing theory, turbulence, water waves, flows in flexible tubes. Prerequisite: Mech 421. Salathe, Blythe

**Mech 424. Unsteady Fluid Flows (3)**
Gas dynamics, finite amplitude disturbances in perfect and real gases; channel flows; three-dimensional acoustics; theories of the sonic boom. Motions in fluids with a free surface; basic hydrodynamics, small amplitude waves on deep water; ship waves; dispersive waves; shallow water gravity waves and atmospheric waves. Hemodynamics; pulsatile blood flow at high and low Reynolds number. Models of the interaction of flow with artery walls. Varley

**Mech 437. (Mat 437) Dislocations and Strengths in Crystals (3)**
Theory and application of dislocations. Geometrical interpretation; elastic properties; force on a dislocation; dislocation interactions and reactions; multiplication. Dislocations in crystal structures. Selected topics in strengthening plastic flow, creep, fatigue and fracture are discussed. Prerequisites: Math 205 or 221, or Met 320; Met 317, or consent of the department chairperson. Chou, Wei

**Mech 450. Special Problems (3)**
An intensive study of some field of applied mechanics not covered in more general courses.

## Engineering Mathematics Courses

**EMA 425. Variational Methods in Science and Engineering (3)**
Variational problems with one independent variable; Euler-Lagrange equations; methods of solution; space and time dependent fields; null Lagrangians and inhomogeneous Dirichlet data; problems with constraints; symmetries and conservation laws; variational approximation methods, Rayleigh-Ritz, Galerkin, finite element, and collocation. Problems and examples will be drawn from the mechanics of solids, fluids, and related fields. Prerequisite: consent of chairman. Edelen

**EMA 450. Special Topics (3)**
An intensive study of some field of engineering mathematics not covered in other courses.

**EMA 490. Thesis**

**EMA 499. Dissertation**

# Military Science

**Professor.** LTC Thomas R. Frankenfield, M.S. (Lehigh), *chairperson.*
**Assistant professors.** MAJ Lawrence A. Deren, B.S. (Lehigh); MAJ Brooks Breece, M.A. (Villanova); CPT William R. Knop, B.A. (Southern Illinois); CPT Alexander K. Kose, B.A. (St. Joseph's); CPT Charles G. Ziegler, B.A. (Duquesne).
**Instructors.** SGM Joseph Edwards III, SFC Fredy Martinez, SSG Earl Pickett.

The Department of Military Science, established in 1919, conducts the Army Reserve Officer Training Corps (ROTC) program at Lehigh University. This is one of the oldest ROTC programs in the nation. The Army ROTC program provides a means for students to qualify for a commission as an officer in the Active Army, Army Reserve, or Army National Guard.

The objectives of the military science program are to develop leadership and management ability in each student; to provide a basic understanding of the Army's history, philosophy, organization, responsibilities, and role in American society; and to develop fundamental professional knowledge and skills associated with officership. These objectives are achieved through classroom instruction, leadership laboratories, field trips, role playing, leadership simulations, and individual assessment and counseling.

Army ROTC offers a four-year program and a two-year program. The four-year program consists of a two-year basic course and a two-year advanced course. The two-year program consists of the two-year advanced course offered to students with previous military experience, and those who have successfully completed a six-week ROTC basic summer camp. Basic course students incur no obligation for service in the Army as a result of taking these courses.

**Basic Course.** The basic course, normally taken in the freshman and sophomore years, provides training and instruction in leadership and basic military subjects, such as the Army's role and organizational structure, history and philosophy of the Army, basic tactics, land navigation, first aid, group dynamics, and leadership traits and characteristics. Basic course students incur no military obligation.

**Advanced Course.** The advanced course is normally taken in the junior and senior years. The instruction includes management, military skills, advanced leadership, logistics, administration, military law, ethics, and professionalism, and includes attendance at ROTC Advanced Camp. Students receive $100 per month subsistence pay during the junior and senior years.

To enroll in the advanced course, an applicant: completes either the basic course or the six-week basic summer camp; or has received basic course credit for previous military experience; and is accepted for enrollment by the university and the department of military science.

**Uniforms and Equipment.** All uniforms and equipment needed by the student for military science courses are supplied by the department. Students are charged only for those items not returned when they leave the program.

**Transfers.** Qualified students transferring from another institution may enter the ROTC program at the appropriate advanced level and year, provided they have received the necessary credits, the recommendation of their former professor of military science (if applicable), and the approval of the university.

**Obligation after graduation.** Upon graduation a student will receive a commission as a Second Lieutenant in either the Active Army or the Reserve Forces. The service obligation is for 8 years to include an initial period of Active Duty of up to 4 years depending upon Army requirements. The remainder of the service obligation will be served in the Reserve Components. The Army may not require the student to serve on Active Duty except for an initial period of Active Duty training of 3 to 6 months. The remainder of the 8 year service obligation will then be served in either the Army Reserve or Army National Guard.

**Graduate studies.** ROTC graduates may request to delay their active service to pursue a full-time course of instruction leading to an advanced degree. Delay does not lengthen the active service obligation unless the degree is obtained at government expense.

**Course credit.** Students in the College of Arts and Science and the College of Business and Economics may substitute military science advanced credits for six hours of electives. In the College of Engineering and Applied Science, six credits of advanced ROTC work are permissible within the normal program of each student, irrespective of curriculum. For curricula that include more than six hours of personal electives in the junior and senior years, inclusion of the more than six hours of ROTC credit with normal programs can be effected only with the approval of academic advisers. All military science credits, including those in the basic course, apply toward the student's over-all cumulative grade point average.

### *Career Opportunities*

Individuals may be commissioned as officers in the United States Army after completion of the ROTC program and the advanced camp. Those cadets who may not have completed a bachelor's degree upon qualifying for commissioning will not begin active duty until completion of the degree requirements. The majority then qualify for active duty in the Army in branches (specialities) such as the Corps of Engineers, Infantry, Armor, Aviation, Field Artillery, Air Defense Artillery, Signal Corps, Military Intelligence, Chemical Corps, Ordnance Corps, Finance, Transportation, Quartermaster, Medical Service Corps, or Nursing. Officers work as leader/managers, specialists, or combinations of the two depending on the assignment.

There are opportunities for advanced military and civilian schooling beginning with nearly three months of training in the branch specialty. A person may also receive an additional specialty in such areas as systems analysis, research and development, foreign area specialization, comptroller, or public affairs, depending on individual expertise. Students may be selected for reserve forces duty. Reserve forces duty provides the student with the opportunity to maintain the options of a military or civilian career upon completion of the program. Those individuals who receive reserve forces duty become officers in the Army Reserve or Army National Guard in their hometown area and essentially have a part-time military career. An officer can earn retirement through both programs after twenty years of service.

**Physical facilities.** Army ROTC uses areas on and adjacent to the university campus to conduct field training. These locations are excellent for most outdoor activities such as orienteering, patrolling, and survival training. Fort Indiantown Gap Military Reservation, located east of Harrisburg, Pa., is used for field training exercises and weapons familiarization during the two annual weekend field exercises. Trips to active Army installations such as Ft. Belvoir, Virginia, Aberdeen Proving Ground, Maryland, and Fort Dix, New Jersey are also available. Other locations used for cadet adventure training are: Ralph Stover State Park (Mountaineering); Delaware and Lehigh rivers (rafting); and the university's Saucon Valley athletic complex.

## *Programs and Opportunities*

**ROTC Scholarship Program.** This program is designed to offer financial assistance to outstanding young men and women entering the ROTC program who are interested in an Army career. Each scholarship provides most tuition, a textbook and supplies allowance, and laboratory fees, in addition to pay of $100 per month for the period the scholarship is in effect. Three- and two-year scholarships are available to outstanding cadets who are currently enrolled in the four-year ROTC program and are completing either their freshman or sophomore years of college. This program is also open to all qualified students who are not currently enrolled in Army ROTC.

Four-year scholarships are open to all students entering ROTC as freshmen. Recipients of an ROTC scholarship are required to complete at least one semester of Indo-European or Asian language prior to commissioning. Applications for scholarship must be made to Headquarters, U.S. Army Cadet Command, Fort Monroe, VA by August 15th prior to the senior year for early selection, but no later than December 1st for normal application. Application booklets are available from most high school guidance offices, or may be obtained from the Military Science Department of the University.

**Two-Year Program.** Students who want to enroll in ROTC after their sophomore year may apply. Applicants must successfully complete a six-week basic ROTC summer camp and have two years of undergraduate or graduate studies remaining. The student is paid for the six-week encampment and receives transportation costs to and from the camp. Individuals begin the advanced course after the basic camp.

**Distinguished Military Graduate (DMG) program.** This is a competitive program that permits outstanding ROTC students to apply for a Regular Army commission immediately upon graduation. At the end of the junior year and upon completion of the advanced summer camp, approximately one third of each senior ROTC class may be designated as Distinguished Military Students (DMS). A student who maintains the same high standards throughout the senior year may qualify for designation as a Distinguished Military Graduate (DMG) and may be offered a Regular Army commission upon graduation.

**Off-campus U.S. Army Training Schools.** Cadets may be selected to attend the following U.S. Army Schools: Airborne School (Fort Benning, Georgia), Air Assault school (Fort Campbell, Kentucky), Ranger School (Georgia and Florida), and Northern Warfare School (Fort Greely, Alaska). This off-campus program is fully funded by the U.S. Army.

**Minor in Military Science.** A minor in Military Science is available in the College of Arts and Science. A minor in Military Science consists of 37 credit hours beyond the basic Military Science course and is designed to provide the student with an academic foundation necessary to support continued intellectual growth and stimulate future inquiry in the realm of civil military affairs and Military Science. Credit hours required are distributed as follows:

Military Science (13)

| | |
|---|---|
| MS 101 | Advanced Military Skills (3) |
| MS 102 | Advanced Leadership (3) |
| MS 113 | Military Command and Staff (3) |
| MS 114 | War, Morality, Ethics and Military Professionalism (3) |
| MS 118 | Special Topics for the Army Officer (1) |

History (3)

| | |
|---|---|
| Hist 310 | American Military History (3) |

International Relations (3) (Select one of the following)

| | |
|---|---|
| IR 1 | World Politics: Evolution of the International System (3) |
| IR 2 | World Politics: Concepts and Principles (3) |
| IR 51 | American Foreign Policy Since 1945 (3) |
| IR 312 | World Affairs Since 1945 (3) |
| IR 371 | Reading in International Relations (3) |

Written Communications (3) (Select one course from one of the following categories)

Creative Writing
Scientific Writing
Writing for Mass Communications

Human Behavior (3) (Select one course in one of the following categories)

General Psychology
Sociology
Anthropology
Ethics

Indo-European or Asian Language (6)

Math Reasoning Course

| | |
|---|---|
| Math 5 | Introduction to Mathematical Thought (3) or More Advanced Course |

Computer Literacy Course

| | |
|---|---|
| CSC 11 | Introduction to Structure Programming (3) or More Advanced Course |

## *Commissioning Requirements*

Individuals must complete either the two- or four-year programs, attend the advanced camp, and receive a college degree, have a CUM GPA of 2.0, and complete all professional military education requirements to become commissioned officers in the United States Army.

## Course Descriptions

Leadership Laboratory is conducted for all students on Monday afternoons. The Leadership Laboratory provides students the opportunity to demonstrate an understanding of the leadership process and develop fundamental military skills.

Instruction at several levels on a variety of subjects with military application provides the context within which students are furnished opportunities to both teach and lead in a group setting. Responsibility is expanded as the student progresses through the program. In the senior year, the students assume the responsibility for the planning, preparation and conduct of the laboratory. Leadership Laboratory is mandatory for all students enrolled in Military Science courses.

**15. The Soldier in Modern Times (1)** fall
The American Army as an institution, its roots, history, customs and traditions and philosophy of leadership. Emphasis on development and role of a professional officer corps. Includes leadership laboratory and one field trip.

**16. Leadership Assessment and Group Dynamics (1)** spring
Role of individual and leader within the group, leader traits and characteristics. Emphasis on problem solving and application. Includes laboratory and FTX.

**23. Topographic Analysis and Land Navigation (2)** fall
Maps as tools in basic terrain analysis and as navigational aids. Emphasis on application and field exercises at individual and small group levels. Includes laboratory and FTX.

**24. Leadership Theory and Development (3)** spring
Contemporary theories, traits and principles. Leadership philosophies, communications, leader-follower relationships, and leadership problem-solving. Leadership simulations. Includes laboratory and FTX.

**101. Advanced Military Skills (3)** fall
Essential junior officer skills: advanced land navigation, principles of war, small unit tactical planning, tactics and techniques of the soldier, team leading techniques, oral communications and trainer skills. Emphasizes application and field experience. Includes laboratory and FTX. Prerequisite: permission of department chairman.

**102. Advanced Leadership (3)** spring
Critical examination of leadership qualities, traits and principles with emphasis on military environment. Self, peer, and instructor

leadership evaluation. Advanced military skills reinforced. Includes laboratory, FTX and a 3 day leadership exercise. Prerequisite: permission of department chairman.

**Advanced ROTC Summer Camp**
This is a six-week training program conducted at Fort Bragg, N.C. Prerequisites are completion of the basic military science courses or their equivalent and MS 101 and 102. The summer camp experience, in coordination with respective engineering curricula, may be used to fulfill the industrial employment requirements of the engineering courses CHE 100, CE 100, EE 100, EI 100, ME 100, and Met 100. Nursing students spend 10 days at Fort Bragg and 5 weeks training in an Army hospital.

**113. Military Command and Staff (3)** fall
Role, authority and responsibility of military commanders and staff in Personnel, Material and Training Management; Military Law; Plans and Operations. Staff procedures, problem solving, decision making and training methods used in military management. Includes leadership laboratory and FTX. Prerequisite: permission of department chairman.

**114. War, Morality, Ethics and Military Professionalism (3)** spring
Development of the Profession of Arms, its fundamental values and institutions. Ethical responsibilities of military professionals in contemporary American society. Moral dimensions of war, just war theory and international law of war. Prerequisite: permission of department chairman.

**118. Special Topics for the Army Officer (1)** spring
Seminar covering special problems and issues dealing with responsibilities of the commissioned officer as leader, manager, and mentor, not covered in other courses. Prerequisite: permission of the department chairman.

Field Training Exercise (FTX) is a two day leadership and skill training exercise conducted at a nearby U.S. Army training facility designed to teach military skills; introduce students to a military environment and teach and evaluate leadership in military situations. Mandatory for all students enrolled in military science courses.

# Modern Foreign Languages

**Professors.** Anna Pirscenok Herz, Ph.D. (Pennsylvania), *chairperson, Russian;* David W. P. Lewis, Dr. de l'Univ. (Sorbonne, Paris), *French;* Anje C. van der Naald, Ph.D. (Illinois), *Spanish;* Lenora D. Wolfgang, Ph.D. (Pennsylvania), *French.*
**Associate professors.** Linda S. Lefkowitz, Ph.D. (Princeton), *Spanish;* David W. Pankenier, Ph.D. (Stanford), *Chinese;* D. Alexander Waldenrath, Ph.D. (Berkeley), *German.*
**Assistant professors.** Marie-Sophie Armstrong, Ph.D. (Oregon), *French;* Antonio Prieto, Ph.D. (Princeton), *Spanish.*
**Adjunct professor.** Victor M. Valenzuela, Ph.D. (Columbia), *Spanish.*
**Adjunct lecturer.** Harriet L. Parmet, M.Sc. Ed. (Temple), *Hebrew.*
**Instructor.** Peter M. Musolf, M.A. (Princeton), *German.*

Languages shown above in *italics* indicate the language normally taught by that faculty member.

Command of foreign languages not only gives the student a deeper insight into his or her native tongue but also opens the door to other cultures, traditions and modes of thought. Knowledge of languages is valuable in a broad range of professions. Linguistic skills are important in journalism, government, international relations, law, the armed forces and international business. The specialist may become a translator, interpreter or teacher. A bachelor of arts degree with a major in languages can be a stepping stone to graduate school in other fields such as law and business. Finally, an ability to read foreign languages is important and often required for research in science and technology. In short, language skills are personally enriching and enhance career prospects.

## *Languages offered*

Lehigh offers Mandarin Chinese, French, German, Hebrew, Japanese, Russian and Spanish.

Courses include writing and speaking, reading and listening, literature, civilization and professional areas such as business and health careers. A number of cultural courses are given in English, but most offerings stress classroom use of the language. Facilities include a German House and an International House. The department has a modern language laboratory. Computer facilities are available.

## *Language Requirements*

The B.A. distribution requirements include a category for foreign language (see page 28). Requirements for the B.A. and B.S. in chemistry include German (preferred), French or Russian (see page 96). The honors major in international relations requires foreign language study. The College Scholar program in the College of Arts and Science; the minors in Latin American studies, Russian Area Studies and in military science require language study. Students taking the B.A. in international relations or in foreign careers are expected to study a language. Students choosing a foreign language at elementary level towards their general studies requirement in the College of Engineering must take a minimum of one year (two courses). Some doctoral programs also require foreign language competence, usually assessed by the department of modern foreign languages.

**Advising.** Because of the sequential nature of language study and the variety of specializations available, the department pays special attention to student advising. Students whose experience, skills and placement scores (Advanced Placement or College Board Achievement Test) do not give them a clear indication of their level of placement should consult with their instructor or the department chairperson. Faculty members responsible for more advanced advising are currently as follows: graduate students, Herz; French major and minor, Wolfgang; German major and minor, Waldenrath; Russian minor and area studies, Herz; Spanish major, van der Naald; Spanish minor, Lefkowitz; and study abroad, Lewis. Both resident and faculty advisers are assigned to the German House.

**Major programs.** The department offers major programs in French, German and Spanish. The candidate for the major is expected to demonstrate adequate written and oral command of the language, as well as knowledge of its literature and culture. A period of study abroad is strongly recommended.

Double majors and Arts-Engineering majors including a language component are well received by employers. Studies in the two areas are carefully coordinated by major advisers.

**Minor programs.** The department offers minor programs in French, German, Russian and Spanish and coordinates these studies with a student's major requirements in any college. A minor in Chinese is planned for 1990.

**Related programs.** These are available in East Asian studies, Foreign Careers, Jewish Studies, Latin American Studies and Russian Studies.

**Language of instruction.** All courses are taught in the target language unless otherwise indicated. Students are thereby rapidly accustomed to considering the language as an active means of communication and not solely as an object of study.

**Courses in English.** The department offers elective courses in English on literary, cultural and social subjects. These courses have no prerequisite and may, in most cases, be taken to fulfill preliminary distribution requirements. One of these courses may be included in the major.

**Study Abroad and Foreign Study Awards.** The department encourages students of foreign languages to spend a summer, a semester, or a full year on an approved program of study abroad. The department offers a limited number of travel scholarships for foreign study to qualified students. Applications should be submitted by November 1 for the spring semester and by March 1 for summer or fall. For credit, transfer students must consult in advance with their major adviser, foreign language adviser, other appropriate departments, the associate dean of Arts and Science, the registrar, and when appropriate, the Office of Financial Aid.

A selective program of foreign summer internships is being developed.

Lehigh offers summer programs through the Lehigh Valley Association of Independent Colleges (LVAIC). Programs are offered in Poitiers (France), Bonn (Germany) and Seville (Spain) for six credits each. A faculty member, acting as program director, accompanies the students. Courses are taught at intermediate and advanced levels, by qualified instructors from host institutions. Summer programs sponsored by the Lehigh-LVAIC Center for Jewish Studies include Hebrew in Israel (see page 30).

Credits and grades are fully transferable under normal LVAIC cross-registration procedures. Interested students should consult with the department of modern foreign languages, Coppee Hall.

**Campus foreign language house.** The German House is recognized, together with the International House, as an important feature of campus life. Students are encouraged to participate in weekly open dinners and to consider living there.

## Foreign Culture and Literature Taught in English

These courses on foreign cultures and comparative topics carry no prerequisites; knowledge of the foreign language is not required.

Language majors may take one course taught in English by the department for credit toward a major requirement. Interested students should consult their language major advisers.

**MFL 21. Russian Literature and Culture I (3)**
Customs, institutions and literary contributions to western civilization. Herz

**MFL 22. Russian Literature and Culture II (3)**
Continuation of MFL 21. Herz

**MFL 43. German Literature in Translation (3)**
One period or theme in German literature.

**MFL 51. Contemporary Hispanic-American Literature (3)**
Reading and discussion of distinguished Latin American writers: Borges, Garcia Marquez, Cortazar and Vargas Llosa.

**MFL 53. The Hispanic World and Its Culture (3)**
Characteristics and values of the people of Spain and Latin America in literary works and other material. Hispanic cultural contributions to Western civilization.

**MFL 61. Cultural Mosaic of Modern Israel (3)** annually
Cultural and religious components of the State of Israel: creative and performing arts and sociological patterns such as population, immigration, ethnic diversity and literature.

**MFL 71. Introduction to Chinese Culture (3)**
Traditional Chinese attitudes and values from a modern perspective. Pankenier

**MFL 321. Russian Realism (3)**
Russian realists of the 19th century; Dostoevsky, Turgenev, Tolstoy, *et al.* Lectures and class discussion in English; collateral reading and written reports in Russian or English. Herz

**MFL 322. Contemporary Soviet Literature (3)**
Socialist realism in Russian literature since 1917. Lectures and class discussion in English; collateral reading and written reports in Russian or English. Herz

# Chinese

The department offers the following courses in Mandarin Chinese. A course in Chinese culture taught in English is listed above, MFL 71. For East Asian studies see page 29.

**Chin 1. Elementary Chinese I (4)**
Spoken and written Mandarin Chinese; the standard romanized transcription system used in the People's Republic; Chinese characters. Basic speech patterns, vocabulary and pronunciation. One weekly laboratory hour.

**Chin 2. Elementary Chinese II (4)**
Continuation of Chin 1; more advanced vocabulary and sentence structures. One weekly laboratory hour. Prerequisite: Chin 1 or equivalent.

**Chin 11. Intermediate Chinese I (3)**
More advanced character texts. Folklore, brief readings in Chinese.

**Chin 12. Intermediate Chinese II (3)**
Continuation of Intermediate Chinese II; more formal oral and written exercises in the vernacular. Prerequisite: Chin 11 or equivalent.

Introduction of Advanced Chinese is planned for 1989/90.

# French

**Preliminary courses.** These may be replaced by advanced standing for students who qualify.

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| Fren 1 | Elementary French I (4) |
| Fren 2 | Elementary French II (4) |
| Fren 11 | Intermediate French I (3) |
| Fren 12 | Intermediate French II (3) |

**Requirements for the major.** A minimum of thirty credit hours is required beyond Fren 12 or 13, as follows:
Fren 143 and 144, Advanced Oral and Written French (6)
Fren 151 and 152, Survey of Literature (6)
Two or three courses from the following: Fren 146, 159, 191, 224, 291 (6-9).
Three or four courses at the 300 level (9-12).

**Requirements for the departmental honors major.** Thirty-six credit hours are needed. Requirements are the same as for the major, plus six additional hours of advanced study on a literary or cultural subject normally taken as an honors thesis (Fren 371) and a 3.20 average in the major.

**Recommended related courses.** Students majoring in French are urged to take elective courses on related subjects, either within or outside the department, as approved by their adviser.

**Requirements for the minor.** Fifteen credit hours are required above Fren 12 or 13 as follows:
Fren 143 (3)
Two or three of 144, 146, 151, 152, 159, 191, 224 (6-9)
One or two courses at 300 level. (3-6)

**Requirements for advanced courses.** Except where otherwise noted, 200- or 300-level courses are open to students having completed six credit hours of French beyond Fren 12. Exceptions require the consent of chairperson.

**Language of instruction.** Courses are normally conducted in French. Courses in French culture taught in English are listed under Foreign Culture above, MFL 31, 33.

## Undergraduate Courses in French

**Fren 1. Elementary French I (4)** fall and spring
Basic conversational French, illustrating essential grammatical principles, reading simple texts and writing. Language laboratory practice.

**Fren 2. Elementary French II (4)** fall and spring
Continuation of Fren 1. Prerequisite: Fren 1 or appropriate Achievement Test score before entrance, or consent of the chairperson.

**Fren 11. Intermediate French I (3)** fall and spring
Completion of grammar and grammar review. Readings and discussion. Prerequisite: Fren 2 or appropriate Achievement Test score before entrance, or consent of chairperson.

**Fren 12. Intermediate French II (3)** fall and spring
Emphasis on readings and discussion. Prerequisite: Fren 11, or appropriate Achievement Test score before entrance, or consent of chairperson.

**Fren 13. Intermediate French II (Oral) (3)**
Emphasis on aural/oral skills as an alternative to French 12. Acceptable for completion of B.A. language requirement. Students may receive credit for French 12 or 13, but not for both. Enrollment limited to 15. Prerequisite: French 11 *and* consent of department chairperson.

**Fren 41. French Pronunciation (1)**
Correct pronunciation of French: the obstacles commonly encountered by American speakers. Articulation, rhythm and pitch. Introduction to the International Phonetic Alphabet. Laboratory work. Prerequisite: any French course previously or concurrently.

**Fren 42. Grammar (1)**
Intensive review of the fundamentals of French grammar. Prerequisite: Equivalent of Fren 2. May be taken for credit only if no previous degree credit in French has been granted; may be audited by others.

## For Advanced Undergraduates And Graduate Students

**Fren 143. Advanced Oral and Written French I (3)** fall
Intensive practice in written and oral French. Prerequisite: Fren 12 or 13, or Achievement Test score of 570 or consent of chairperson.

**Fren 144. Advanced Oral and Written French II (3)**
Continuation of Fren 143, with emphasis on oral work. Prerequisite: Fren 12 or 13, or Achievement Test score of 570 or consent of chairperson.

**Fren 146. French for Business and Foreign Careers (3)**
For students who want "professional" French but are uncertain of their readiness for highly specialized material. Intensive revision of grammar, reading of simple contemporary texts, conversation, composition and letter writing. Prerequisite: Fren 12 or 13 or consent of the chairperson. Lewis

**Fren 151. Survey of French Literature I (3)**
From the Middle Ages through the 18th century. Prerequisite: Fren 12 or 13 or consent of the chairperson. Wolfgang

**Fren 152. Survey of French Literature II (3)**
Representative works of the 19th and 20th centuries. Prerequisite: Fren 151 or consent of the chairperson.

**Fren 159. The French-Speaking World and Its Culture (3)**
Cultural, social and artistic development of France and the French-speaking world. Prerequisite: Fren 12 or 13.

**Fren 181. French Cultural Program (1-6)**
A summer program abroad. Formal instruction in the French language and direct contact with the people and their culture during one or two months in a French-speaking country. (For LVAIC courses, see Fren 191 below.)

**Fren 223. Love and the French Novel (3)**
Representative works from each period of French literature from *Tristan et Iseult* and *La Princesse de Clèves* to Gide's *L'Immoraliste*. Style, themes, myths and story patterns are analyzed. Prerequisite: any of Fren 143, 144, 151, 152 or 159. Wolfgang

**Fren 224. Great French Plays (3)**
Evolution of French drama through study of master works, from the 17th century to the present. Prerequisite: any of Fren 143, 144, 151, 152 or 159.

**Fren 268. World Literature Written in French (3)**
Major authors from areas outside Europe, such as Canada, Africa, and the Caribbean. Prerequisite: any of Fren 143, 144, 151, 152 or 159.

**Fren 271. Readings (3)**
Study of the works of some author or group of authors or a period, or of a literary theme. May be repeated once for credit. Prerequisite: Fren 143, 144, 151 or 152 or consent of the chairperson.

**Fren 281. French Cultural Program (1-6)**
A program in a French-speaking country offering formal language courses and cultural opportunities. (For LVAIC courses, see Fren 291 below.) Prerequisite: consent of the chairperson.

**Fren 301. Advanced Composition and Translation (3)**
Techniques of translation. Literary, political, and technical texts. Essay-writing techniques and free composition. Prerequisite: a 200-level course or consent of the chairperson.

**Fren 303. Renaissance Poetry (3)**
Study of the major poets of the period. Wolfgang

**Fren 305. Prose in the 16th Century (3)**
Analysis of fiction, memoirs, historical documents, including the works of Rabelais, Montaigne, and Marguerite de Navarre. Wolfgang

**Fren 309. Medieval French Literature (3)**
Introduction to Old French from *La Chanson de Roland* to François Villon. Wolfgang

**Fren 311. French Classicism (3)**
French classical theater, novel and criticism, with emphasis on Corneille, Racine, Molière, Pascal, Lafayette, Malherbe and Boileau.

**Fren 313. The Age of Enlightenment (3)**
The *Philosophes* and *Encyclopédistes* of the 18th century, with emphasis on Voltaire, Rousseau, Montesquieu and Diderot.

**Fren 315. 19th Century Poetry (3)**
Parnassian, Symbolist and Post-Symbolist eras. Lewis

**Fren 317. The Romantic Movement (3)**
The Romantic movement in France with readings from its principal exponents. Lewis

**Fren 318. Drama in the Twentieth Century (3)**
Contemporary French drama with an analysis of its origins and movements. Armstrong, Lewis

**Fren 319. Twentieth Century Novel and Poetry (3)**
Detailed study of representative major works. Armstrong

**Fren 345. Advanced French for Business and Foreign Careers (3)**
Understanding and writing French for business and international affairs. Readings and oral presentations of current interest, with technical vocabulary (marketing, finance, industry, agriculture, communications, transport, real estate, economic relations, environment, etc). Prerequisite: any of Fren 143, 144, 146, 159 or consent of chairperson. Lewis

**Fren 369. Readings (3)**
Advanced study of an author, period or theme. Topics vary. May be repeated once for credit.

**Fren 370. Internship (1-6)**
Designed to give advanced qualified students the chance to acquire field experience and training with selected firms and governmental agencies in French-speaking countries. Assigned readings, written reports, and employer performance evaluations are required. Prerequisites: French 143 or 144 and approval of faculty committee on internship.

**Fren 371. Independent Study (1-6)**
Special topics under faculty guidance, including honors thesis. May be repeated once for credit. Prerequisite: consent of the chairperson.

# German

**Preliminary courses.** These may be replaced by other courses when a student qualifies for advanced standing.

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| Germ 1 | Elementary German I (3) |
| Germ 2 | Elementary German II (3) |

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| Germ 11 | Intermediate German I (3) |
| Germ 12 | Intermediate German II (3) |

**Requirements for the major.** A minimum of thirty credits beyond Germ 12 of which three credits must be a junior year writing course in the German section. Emphasis should be upon 200- and 300-level courses.

**Requirements for the departmental honors major.** Requirements are the same as for the major, plus: two additional advanced courses at the 300 level; dissertation or comprehensive examination (written or oral); an average of 3.50 in courses in the major.

**Recommended related courses.** Students majoring in German are urged to take courses on related subjects, either within or outside the department, as approved by their adviser.

**Requirements for the minor.** Fifteen credits above Germ 12 are required including at least one at 300-level.

**Requirements for advanced courses.** The prerequisite for all 200-level courses is at least one three-credit course taught in German beyond Germ 12 or equivalent. The prerequisite for all 300-level courses is at least two three-credit courses beyond Germ 12 (course in English excluded) or equivalent. Prerequisite may be waived by consent of the chairperson.

**Language of instruction.** Courses are normally conducted in German. Courses conducted in English are listed under MFL courses.

## Undergraduate Courses in German

**Germ 1. Elementary German I (3)**
Fundamentals of German; reading of simple texts; simple conversation and composition; vocabulary building. Three class hours plus one laboratory or drill hour each week. No previous German required.

**Germ 2. Elementary German II (3)**
Continuation of German 1, including reading of more advanced texts. Three class hours plus one laboratory or drill hour each week. Prerequisite: Germ 1, or two units of entrance German, or consent of the chairperson.

**Germ 5. German Pronunciation (1)**
Practice in pronunciation, articulation, rhythm and pitch. Includes laboratory practice. Strongly recommend for all students of the language at all levels.

**Germ 11. Intermediate German I (3)**
Review of grammar, composition, reading of intermediate texts, vocabulary building. Prerequisite: Germ 2 or four units of entrance German or consent of chairperson.

**Germ 12. Intermediate German II (3)**
Continuation of Germ 11. Prerequisite: Germ 11 or consent of chairperson.

**Germ 63. Introduction to German Culture (3)**
Lectures, readings and discussion of selected aspects of German culture. Prerequisite: Germ 12 or equivalent, or consent of chairperson.

**Germ 65. Introduction to the German Literary Tradition (3)**
Representative works from one or more of the major periods of German literature. Prerequisite: Germ 12 or equivalent, or consent of chairperson.

**Germ 67. Conversation and Composition (3)**
Intensive practice in oral and written German. Prerequisite: Germ 12 or equivalent, or consent of chairperson.

**Germ 81. German Cultural Program (1-6)**
Summer program abroad. Formal instruction in the language and the culture of a German speaking country.

## For Advanced Undergraduates And Graduate Students

**Germ 201. Survey of German Literature I (3)**
German literature to the second half of the 18th century. Readings, literature and discussion of representative works.

**Germ 202. Survey of German Literature II (3)**
From the Age of Goethe to the present. Readings, lectures and discussion of representative works.

**Germ 211. Introduction to German Drama (3)**
Drama as a literary genre; plays from various periods of German Literature.

**Germ 214. Goethe's "Faust" (3)**
Study of Goethe's play with an introduction to the Faust tradition.

**Germ 241. Advanced Composition and Conversation (3)**
Conducted in German.

**Germ 250. Special Topics (1-3)**
Literary and linguistic topics not covered in regular courses. May be repeated for credit.

**Germ 281. German Cultural Program (1-6)**
Study abroad. Formal instruction in German and direct contact with the people and their culture during at least one month in a German-speaking country. Prerequisites: Germ 63, 65, or 67, or consent of the chairperson.

**Germ 301. Medieval German Literature (3)**
Lectures and readings in medieval literature in translation. Introduction to Middle High German.

**Germ 302. Renaissance, Reformation and Baroque (3)**
Writers and literary movements from the end of the Middle Ages through the Baroque.

**Germ 303. German Romanticism (3)**
Early and late Romanticists.

**Germ 304. Literature of the GDR (3)**
Representative East-German writers.

**Germ 305. 20th-Century German Literature (3)**
Topics in German literature of the 20th century.

**Germ 325. 19th-Century German Literature (3)**
Representative writers of post-Romanticism.

**Germ 341. Advanced Phonetics, Linguistics, Composition, Conversation and Translation (3)**
Essay writing and translation from and into German.

**Germ 344. The Age of Enlightenment and Classicism (3)**
Selected works of the period.

**Germ 350. Special Topics (1-3)**
Literary or linguistic topics not covered in regular courses. May be repeated for credit. Prerequisite: permission of the chairperson.

**Germ 370. Internship (1-6)**
Designed to give advanced qualified students the chance to acquire field experience and training with selected firms and governmental agencies in German-speaking countries. Assigned readings, written reports, and employer performance evaluations are required. Prerequisite: Germ 67 and/or approval of the staff in German.

# Hebrew

The department offers courses both separately and in the context of the Jewish Studies minor (see page 30).

**Language of instruction.** Courses are normally conducted in

Hebrew. A course in Hebrew culture taught in English is listed under Foreign Culture above, MFL 61.

**Hebr 1. Elementary Modern Hebrew I (3)** fall
Classroom and laboratory instruction to develop hearing, speaking, reading and writing the language. Cultural, ethnic and religious dimensions of Israeli society. Tapes, textural materials, short stories. No previous study of Hebrew required.

**Hebr 2. Elementary Modern Hebrew II (3)** spring
Continuation of Hebrew 1 utilizing the audio-lingual approach. Fundamentals of the language, structure and sounds; the Hebrew verb; reading and vocalized stories; written exercises; tapes; short stories. Prerequisite: Hebr 1 or its equivalent.

**Hebr 11. Intermediate Modern Hebrew I (3)** fall
Classroom and laboratory instruction to develop fundamental patterns of conversation and grammar; composition, reading of texts, laboratory work and sight reading; comprehension, speaking, reading and writing of unvocalized materials. Prerequisite: Hebr 2 or qualifying examination.

**Hebr 12. Intermediate Modern Hebrew II (3)** spring
Continuation of Hebrew 11. Reading of texts, including selected short stories, outside reading and supplementary material; increased emphasis on oral presentation. Prerequisite: Hebr 11 or approval of the department chairperson.

# Japanese

Elementary and intermediate Japanese language and Japanese culture are available at Lafayette College in association with LVAIC.

Introduction of Elementary Japanese at Lehigh is planned for 1989/90.

# Russian

**Requirements for minor.** Eighteen credit hours of Russian are required not including MFL 21, 22, 321 or 322. For Russian studies minor, see page 31.

**Language of instruction.** Courses are normally conducted in Russian. Courses in Russian culture taught in English are listed under Foreign Culture above, MFL 21, 22, 321 and 322.

**Russ 1. Elementary Russian I (3)** fall
Classroom and laboratory introduction to the fundamentals of conversational and grammatical patterns; practice in pronunciation, simple conversation, reading and writing.

**Russ 2. Elementary Russian II (3)** spring
Continuation of Russ 1. Prerequisite: Russ 1 or two units of entrance Russian.

**Russ 11. Intermediate Russian I (3)** fall
Classroom and laboratory practice in conversation. Development of reading and writing skills. Prerequisite: Russ 2 or three units of entrance Russian.

**Russ 12. Intermediate Russian II (3)** spring
Continuation of Russ 11. Prerequisite: Russ 2 or 11, or four units of entrance Russian.

**Russ 31. Russian in Science, Economics, and Industry I (3)** fall
Readings and conversations about nonliterary topics including the social and natural sciences, business, economics and industry. Prerequisite: Russ 12. Herz

**Russ 32. Russian in Science, Economics, and Industry II (3)** spring
Continuation of Russ 31. Prerequisite: Russ 12 or 31. Herz

**Russ 41. Conversation and Composition I (3)** fall
Intensive practice in oral and written Russian; laboratory practice in aural comprehension. Readings and discussions on Russian literature and culture. Prerequisite: Russ 12, or three units of entrance Russian. Herz

**Russ 42. Conversation and Composition II (3)** spring
Continuation of Russ 41. Prerequisite: Russ 41. Herz

**Russ 251. Special Topics (3)** fall
Intensive study of literary or linguistic topics. Prerequisite: Russ 42. May be repeated for credit. Herz

**Russ 252. Special Topics (3)** spring
Intensive study of literary or linguistic topics. Prerequisite: Russ 42 or 251. May be repeated for credit. Herz

**Russ 370. Internship (1-6)**
Designed to give advanced qualified students the chance to acquire field experience and training with selected firms and governmental agencies in Russian-speaking countries. Assigned readings, written reports, and employer performance evaluations are required. Prerequisites: Russ 41 or 42 and approval of faculty committee on internship.

**Russ 391. Special Topics (1-3)**
Independent study or research under faculty guidance on a literary, linguistic, or methodological topic. May be repeated once for credit. May be used to satisfy the doctoral language requirement. Prerequisites: undergraduate degree and consent of chairperson. Herz

# Spanish

**Preliminary courses.** These may be replaced by other courses if students achieve advanced standing.

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| Span 1 | Elementary Spanish I (3) |
| Span 2 | Elementary Spanish II (3) |
| Span 11 | Intermediate Spanish I (3) |
| Span 12 | Intermediate Spanish II (3) |

**Requirements for the major.** A total of thirty credit hours are required above Span 12 as follows: Span 141, 142 or 255, 151, 152. Span 191 or 291 may be considered.

Four courses at the 300-level: at least two must be selected from Peninsular literature and at least two from Spanish American literature, the remaining two courses at the 100-level and above.

**Requirements for departmental honors major.** Thirty-six credit hours are required above Span 12 as follows: thirty credits, as for the major; six additional credit hours on the 300-level; a 3.50 average in the major.

**Requirements for the minor.** Fifteen credits are required above Span 12, as described for three minor tracks.

*Spanish American Track.* Span 141, 142 or 255, 152, a 300-level course in Spanish American literature, one course at the 100-level or above.

*Peninsular Track.* Span 141, 142 or 255, 151, a 300-level course in Peninsular literature, one course at the 100-level or above.

*Professional Track.* Span 141, 142 or 255, 211, 151 or 152, one course at the 100-level or above.

**Recommended related courses.** Students majoring in Spanish are urged to take courses on related subjects inside or outside the department, as approved by their adviser.

**Requirements for advanced courses.** The normal prerequisite for 200- and 300-level literature courses in Spanish is Span 151 and/or 152. Exceptions require consent of chairperson.

**Language of instruction.** Courses are normally conducted in Spanish. Culture courses taught in English are listed under Foreign Culture and Literature Taught in English.

## Undergraduate Courses in Spanish

**Span 1. Elementary Spanish I (3)** fall and spring
Basic conversational Spanish illustrating essential grammatical principles. Reading of simple texts and writing. Lab required.

**Span 2. Elementary Spanish II (3)** fall and spring
Continuation of Span 1. Prerequisite: Span 1 or equivalent.

**Span 11. Intermediate Spanish I (3)** fall and spring
Grammar review. Contemporary readings. Practice of speaking and writing. Prerequisite: Span 2 or equivalent.

**Span 12. Intermediate Spanish II (3)** fall and spring
Grammar review. Readings of Spanish and Latin American authors. Emphasis on acquiring oral and written fluency. Prerequisite: Span 11 or equivalent.

**Span 131. Communicating in Spanish for Medical Personnel (1-3)**
For prospective medical personnel communicating with Spanish-speaking patients. Dialogues, health-care vocabulary. Review of grammar. Language laboratory practice. Prerequisite: Span 12 or equivalent. Lefkowitz

**Span 133. Phonetics and Pronunciation (3)**
Comparison of Spanish and English sounds; descriptions of Spanish vowels and consonants in their various positions. Oral practice in Language Laboratory. Special emphasis on accent and intonation patterns. Prerequisite: Span 2. Staff

**Span 141. Advanced Grammar (3)** fall
Intensive review of Spanish grammar with stress on finer points. Analysis of syntax and style. Prerequisite: Span 12 or equivalent. Staff

**Span 142. Advanced Conversational Spanish (3)** spring
Conversational practice stressing the building of vocabulary, based on literary texts and topics of general interest. Designed to stimulate fluent and spontaneous use of spoken Spanish. Enrollment limited to 15. Prerequisite: Span 12 or equivalent. Staff

**Span 151. Cultural Evolution of Spain (3)** fall
The historical and cultural evolution of Spain. Discussion of major literary works in their cultural and historical contexts. Prerequisite: Span 12. Lefkowitz or van der Naald

**Span 152. Cultural Evolution of Latin America (3)** spring
The historical and cultural evolution of Latin America. Prerequisite: Span 12 or equivalent. Prieto

## For Advanced Undergraduates And Graduate Students

**Span 211. Practical Business Spanish (3)**
For students with a basic knowledge of Spanish: the language in business, law, international and social relations. Letter-writing, comprehension of technical texts, specialized professional vocabulary and review of grammar. Prerequisite: Span 141 or equivalent. Lefkowitz

**Span 212. Writing Skills (3)**
Improving writing proficiency through practice in composition and translation. Prerequisite: Span 141 or equivalent. Lefkowitz

**Span 231. Spanish American Literature (3)**
Literature of the pre-Colombian, conquest and colonial periods. Oral and written reports. Prerequisite: Span 151 or 152.

**Span 255. Improvisational Theater Games in Spanish**
For students who have some fluency in the language and who wish to practice and improve their oral Spanish in a creative setting. Enrollment limited to 15. Prerequisite: Span 141 or equivalent. van der Naald

**Span 263. The Spanish American Short Story (3)**
Comparative study of the literary problems posed by the work of significant short-story writers such as Quiroga, Borges, Cortázar, Ribeyro, and others. Prerequisite: Span 152. Prieto

**Span 281. Spanish Cultural Program (1-6)**
A program abroad. Formal instruction in Spanish grammar, conversation and culture during one or more months in Spain or Latin America on an approved program. (For LVAIC courses, see Span 191 and 291 below.) Prerequisite: Span 12.

**Span 303. Don Quijote (3)**
Reading and critical analysis. Prerequisite: Span 151. Lefkowitz

**Span 305. Spanish Literature of the Middle Ages (3)**
Reading and discussion of outstanding works such as *El Cid, El Libro de Buen Amor* and *La Celestina*. Topics vary. Prerequisite: Span 151. Lefkowitz

**Span 308. Peninsular Literature Since 1939 (3)**
Reading and discussion of representative contemporary Spanish poets, playwrights and novelists. Prerequisite: Span 151. van der Naald

**Span 310. Literature of 19th-Century Spain (3)**
Poetry, novels and plays that exemplify the literary movements of Romanticism, Realism and Naturalism. Topics vary. Prerequisite: Span 151. van der Naald

**Span 317. Twentieth-Century Spanish Theater (3)**
Prerequisite: Span 151. van der Naald

**Span 320. Literature of the Spanish Caribbean (3)**
Study of representative works with emphasis on Cuba and Puerto Rico. Writers include Barnet, Carpentier, Sanchez, and Rodriguez Julia. Prerequisite: Span 152. Prieto

**Span 321. Children and Adolescents in Contemporary Spanish American Literature (3)**
Discussion of narrative techniques and the category of the self as they relate to the images of adolescence and childhood in works by such authors as Vargas Llosa, Reinaldo Arenas, Jose Bianco, and Silvina Ocampo. Prerequisite: Span 152. Prieto

**Span 322. The Short Novel in Contemporary Spanish American Literature (3)**
Reading and discussion of a narrative form which is exemplified by the work of Garcia Marquez, Onetti, Rulfo, Bioy Casares, and others. Prerequisite: Span 152. Prieto

**Span 323. Literature and Revolution in Contemporary Cuba (3)**
Study of works written after 1959 by dissident, non-dissident, and exiled authors (Desnoes, Norberto Fuentes, Benitez Rojo, Cabrera Infante). Discussion of problems raised by the social function of intellectuals and of literature, as they relate to themes, modes of writing, genres. Prerequisite: Span 152. Prieto

**Span 324. Marginal Groups in Spanish American Literature (3)**
Reading and discussion of representative works that portray those who have been excluded from the main culture. Authors to be read are Hernández, Sarmiento, Alegría, Guillén, and Carpentier. Prerequisite: Span 152. Prieto

**Span 379. Internship (1-6)**
Designed to give advanced qualified students the chance to acquire field experience and training with selected firms and governmental agencies in Spanish-speaking countries. Assigned readings, written reports, and employer performance evaluations are required. Prerequisites: Span 141 or 142 and approval of faculty.

**Span 391. Special Topics (3)**
Study of an author, theme or period. Topics vary. May be repeated once for credit. Prerequisites: Span 151 or 152 and at least one 300-level course. Staff

# LVAIC Summer Programs

These courses are offered under the cooperation agreement with the Lehigh Valley Association of Independent Colleges. They may be incorporated into foreign language majors and minors with the permission of the appropriate advisor.

## French

**Fren 191. French Language and Culture II Abroad (6)**
Intensive practice in France of conversational French, rapid review of basic grammar, the reading and analysis of moderately difficult

texts, as well as the development of writing skills, supplemented by the study of selected aspects of contemporary French civilization (LVAIC program). Prerequisites: consent of chairperson and proficiency examination in France.

**Fren 291. French Language and Culture III Abroad (6)**
Intensive practice in France of spoken and written French, aimed at providing the student with extensive proficiency of expression and the ability to discriminate linguistic usage. Emphasis on idiomatic expressions and an introduction to stylistics. Reading and analysis of more difficult texts. Supplemented by in-depth study of selected aspects of contemporary French civilization (LVAIC program). Prerequisites: consent of chairperson and proficiency examination in France.

## German

**Germ 191. German Language and Culture II Abroad (6)**
Intensive practice in Germany of conversational German, rapid review of basic grammar, the reading and analysis of moderately difficult texts, as well as the development of writing skills, supplemented by the study of selected aspects of contemporary German civilization (LVAIC program). Prerequisites: consent of chairperson and proficiency examination in Germany.

**Germ 291. German Language and Culture III Abroad (6)**
Intensive practice in Germany of spoken and written German, aimed at providing the student with extensive proficiency of expression and the ability to discriminate language usage. Emphasis on idiomatic expressions and an introduction to stylistics. Reading and analysis of more difficult texts. Supplemented by in-depth study of selected aspects of contemporary German civilization (LVAIC program). Prerequisites: consent of chairperson and proficiency examination in Germany.

## Hebrew

For courses in Israel including study of Hebrew, see Jewish Studies, page 30.

## Spanish

**Span 191. Spanish Language and Culture II Abroad (6)**
Intensive practice in Spain of conversational Spanish, rapid review of basic grammar, the reading and analysis of moderately difficult texts, as well as the development of rudimentary writing skills, supplemented by the study of selected aspects of contemporary Spanish civilization. Prerequisites: consent of chairperson and proficiency examination in Spain.

**Span 291. Spanish Language and Culture III Abroad (6)**
Intensive practice in Spain of spoken and written Spanish aimed at providing the student with extensive proficiency of expression and the ability to discriminate linguistic usage. Emphasis on idiomatic expressions and an introduction to stylistics. Reading and analysis of more difficult texts. Supplemented by in-depth study of selected aspects of contemporary Spanish civilization. Prerequisites: consent of chairperson and proficiency examination in Spain.

# Music

**Associate professors.** Paul Salerni, Ph.D. (Harvard), *chairman;* Jerry T. Bidlack, M.F.A. (Boston U.); Steven Sametz, D.M.A. (Wisconsin).
**Assistant professor.** Nadine Sine, Ph.D. (N.Y.U.).
**Adjunct professor.** Nancy S. Bidlack, M.M. (Temple).
**Marching Band director.** Clark J. Hamman, B.S. (Wilkes).
**Varsity Band director.** Peter Schultz, M.M. (Stony Brook).
**Instrumental instructors.** John Falcone, bassoon; Allison Herz, clarinet; Frank DiBussolo, electric guitar; Robin Kani, flute; Richard Metzger, guitar; Louis Czechowski, jazz piano; Mary Watt, oboe; Kim Heindel, organ; James Barnes, percussion; Helen Beedle, piano; Sandra Dennis, piano; Leander Bien, piano; Mark Hulsebos, saxophone; Greg Barnett, string bass; James Brown, trombone; Lawrence Wright, trumpet; Scott Force, tuba; Linda Kistler, violin, viola; Nancy Bidlack, violoncello; Carmen Pelton, voice.

Located in Lamberton Hall, the music department offers courses in music history, literature, theory, and composition, in addition to providing a wide range of performance experience in instrumental and vocal ensembles, and private instruction. Lamberton houses a listening library, practice rooms, a small collection of instruments, an electronic studio, a computer assisted ear-training facility, and a large concert and rehearsal room.

A student graduating with the music major will have gained a strong foundation in the basics of music theory and substantial exposure to the style and repertoire of western music from the Middle Ages to the present. This curriculum will prepare a student to continue graduate studies in musicology, music theory, or composition. A music major taken in conjunction with a business major may lead to a variety of careers in arts management or in the recording and music publishing industries. Some students may find that a double major or a minor in music will provide the basis for a life-long involvement with an art form which does not necessarily generate income, but gives lasting enjoyment.

**Major program.** Students majoring in music must take 29 credit hours (beyond Mus 20 and 81) including 11 hours in music theory (Mus 111, 212, 213), 9 in music history (any three from Mus 133, 134, 137, 138), and 3 in performance courses (Mus 22-78). The remaining courses in the major are elective and may include 3 additional credits in performance courses.

**Minor program.** The minor requires 17 credits and may include Mus 20 and 81. The program is designed to be very flexible but must include one theory course (Mus 81 or 111), one music history or literature course (Mus 20, 131-138), and two performance courses (Mus 22-78). The student may choose the remaining courses from the departmental offerings, including up to three additional performance courses.

**Private lessons.** A wide variety of instruments and voice lessons may be taken for one credit. They must be arranged through the department at set fees that are *not* included in tuition.

**Performing groups.** Admission to band, choir, ensembles, and orchestra is by audition, and students receive one credit per semester by registering for the appropriate course number. Although there is no limit to the number of courses in this series that may be taken, students should check with their advisor to determine the number that may be applied toward graduation (e.g. only eight credits are applicable in the College of Arts and Science).

**Music at Lehigh.** The department sponsors *Music at Lehigh,* a professional concert series of about ten performances a year open to students and public without charge. Recent appearances include the Orpheus Chamber Orchestra; Calliope, A Renaissance Band; and the Performer's Committee for Twentieth-Century Music. The Ralph N. Van Arnam Chamber Music Series, inaugurated in 1980, presents several concerts each year.

## Course Offerings

**20. Introduction to Musical Literature (3)** fall-spring
Musical style approached through works from the Middle Ages to the present studied in historical and social settings. Emphasis on listening techniques and acquaintance with the masterpieces of Western music. Sine

**21-78.** Applied music and performance courses may be repeated for credit up to eight times. Prerequisite: consent of the chairperson or audition by faculty member responsible for the course.

**21. Marching Band (1)** fall
**22. Wind Ensemble (1)** spring
**23. Varsity Band (1)** spring
**24. Jazz Ensemble (1)** fall-spring
**31. University Choir (1)** fall-spring
**32. Choral Union (1)** fall-spring
**41. String Ensemble (1)** fall-spring
**42. Woodwind Ensemble (1)** fall-spring
**43. Brass Ensemble (1)** fall-spring
**44. Baroque Ensemble (1)** fall-spring

**45. Renaissance Ensemble (1)** fall-spring
**46. Ensemble with Piano (1)** fall-spring
**47. Vocal Ensemble (1)** fall-spring
**48. Mixed Ensemble (1)** fall-spring
**61. String Orchestra (1)** fall-spring
**71. Private Piano Study (1)** fall-spring
**72. Private Vocal Study (1)** fall-spring
**73. Private String Study (1)** fall-spring
**74. Private Woodwind Study (1)** fall-spring
**75. Private Brass Study (1)** fall-spring
**76. Private Percussion Study (1)** fall-spring
**77. Private Organ Study (1)** fall-spring
**78. Other Private Study (1)** fall-spring

**81. Fundamentals of Music Theory (3)** fall-spring
Introduction to rhythm, pitch and timbre; melody, counterpoint and harmony; analysis, composition, ear training, keyboard harmony, and sight singing. Bidlack

**111. Theory I: Principles of Harmonic Analysis (3)** fall-spring
Exercise in counterpoint and harmony. Ear training, sight singing, and analysis. Prerequisite: Mus 81 or equivalent.

**131. Major Genres (3)** fall or spring
Evolution of a single kind of musical composition. Title varies: Opera, Symphony, etc. May be repeated for credit as title varies. Prerequisite: Mus 20, or 81, or consent of the chairperson.

**132. Composer and Era (3)** fall or spring
Life and development of a composer's style viewed in historical context. Title varies: Bach, Beethoven, Mozart, etc. May be repeated for credit as title varies. Prerequisite: Mus 20, or 81, or consent of the chairperson. Sine

**133. History: Medieval and Renaissance Music (3)** fall, odd-numbered years
Development of musical style from early Christian chant to the sacred and secular forms of the late sixteenth century, viewed in cultural contexts. Mus 20 or 81. Sine

**134. History: Baroque and Classical Music (3)** spring, even numbered years
The major genres and composers of the 17th and 18th centuries studied in their cultural context. Prerequisite: Mus 20 or 81. Sine

**137. History: Romantic Era (19th century) (3)** fall, even numbered years
Study of the major composers and their works from late Beethoven to Mahler and Debussy. Prerequisite: Mus 20 or 81. Sine

**138. History: Twentieth-Century Music (3)** spring, odd-numbered years
Beginning with the major trends at the turn of the century, a study of the important composers and works of our century to the present. Prerequisite: Mus 20 or 81.

**153. Electronic Music (3)** fall-spring
Electronic music—its evolution and techniques. Introduction to the history of electronic music; tape recording, tape manipulation, tape loops, mixing, the use of the voltage controlled analog synthesizer, digital delay, etc. Emphasis on developing a compositional idiom that utilizes these instruments and techniques. Prerequisite: consent of the department chairperson. Salerni

**154. Electronic Music (3)** spring
Composition in the electronic medium. Review of live analog techniques and digital delay, introduction to digital synthesis and recording. Emphasis on individual compositional projects and preparation for public concert. Prerequisite: Mus 153. Salerni

**212. Theory II: Counterpoint (4)** spring, odd-numbered years
Writing and analyzing pieces in Renaissance and Baroque contrapuntal styles. Ear training and keyboard skills. Prerequisite: Mus 111.

**213. Theory III: Form and Analysis (4)** spring, even-numbered years
Analyzing and writing pieces in classical and romantic forms. Exercises in chromatic harmony. Ear training and keyboard skills. Prerequisite: Mus 111.

**220. Composition (3)** spring
Applications of the principles of Mus 81 and 111 to compositional practice. Prerequisite: Mus 111, or equivalent, or consent of the department chairperson. Salerni

**251. Special Topics (1-3)**
Study of musical topics or work in musical history or composition not covered in regular courses, or continuation of study of topics or of projects in composition or history begun in regular courses. May be repeated for credit. Prerequisite: consent of the department chairperson.

# Natural Science

Charles B. Sclar, Ph.D. (Yale), *director,* natural science program.

This major program provides students with a broad background in the fundamentals of mathematics and science and the opportunity to concentrate to a reasonable extent in one area of science.

The program leads to a Bachelor of Arts degree and is designed especially for the following: 1. those students who want preparation for graduate work or careers in certain of the derivative or interdisciplinary sciences or related professional fields (oceanography, astronomy, psycho-physiology, medicine or dentistry, etc.); 2. those students who plan to teach in secondary schools or community colleges; and 3. those students without fixed career objectives who want undergraduate training in science.

Students who register for the program are required to select an area of concentration (or option) that must be approved by the dean of the College of Arts and science and the director of the program. The option may be chosen in chemistry, biology, geology, psychology, or in an approved interdisciplinary area (biophysics, marine science, biochemistry, computer science, etc.). Courses included in the option are worked out individually for the student by the major adviser.

Qualified students may be given permission at the end of the junior year to enter a program whereby they are able to begin work toward a graduate degree (master of arts, master of science, or master of education) during the senior year. Students enrolled in this program often complete all course requirements for the master's degree with one year of study beyond the bachelor's degree.

**required preliminary courses**

| | |
|---|---|
| Math 21, 22, 23 | Analytic Geometry and Calculus I, II and III (12) |
| Phys 11, 12 | Introductory Physics I and Laboratory I (5) |
| Phys 21, 22 | Introductory Physics II and Laboratory II (5) **or** |
| Phys 13, 14 | General Physics and Laboratory (4) |
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |
| Geol 21 | Principles of Geology (3) **or** |
| Astr 1 | The Solar System (3) |
| Biol 21, 22 | Principles of Biology and Introduction to Laboratory (4) **or** |
| Psyc 1 | Introduction to Psychology (3) |

**required major courses**

| | |
|---|---|
| Chem 51, 52 | Organic Chemistry (6) **and** |
| Chem 53, 54 | Organic Chemistry Laboratory (3) **or** |
| Chem 31 | Chemical Equilibria in Aqueous Systems (3) **and** |
| Chem 187 | Physical Chemistry I (3) |
| Math | elective (3) |
| Option | (24) |

Note: The mathematics elective and courses included in the option are taken with approval of the major adviser.

Students registered for this major normally are expected to choose their option no later than the second semester of the sophomore year.

# Philosophy

**Professors.** John E. Hare, Ph.D. (Princeton); Robert F. Barnes, Jr., Ph.D. (Berkeley); Steven Louis Goldman, Ph.D. (Boston), *Andrew W. Mellon Distinguished Professor in the Humanities;* J. Ralph Lindgren, Ph.D. (Marquette); Norman P. Melchert, Ph.D. (Pennsylvania), *acting chairperson.*
**Assistant professors.** Gordon Bearn, Ph.D. (Yale); Robin S. Dillon, Ph.D. (Pittsburgh).

The study of philosophy does several things for a student. It improves certain skills, such as the ability to analyze and evaluate arguments, to identify faulty reasoning and to reason well, and to read and understand a difficult and complex text. It provides an acquaintance with the great works in philosophy which have helped form our culture. It teaches what our contemporaries are thinking, for example, about whether moral and aesthetic standards are objective, or when the claims to have knowledge can be justified, or how the mind is related to the brain. It identifies the important philosophical issues raised by areas of human activity such as medicine, business, religion, science and the law. Students of philosophy are studying some of the most important foundations of their view of themselves and their world.

The major program is substantial enough to prepare a student for subsequent graduate study. There is also a wide variety of courses of general interest to students from all three undergraduate colleges. The program has the flexibility to supplement the major with coursework relevant to a variety of careers. Some of our majors have gone directly into banking, communications, insurance, marketing and publishing, immediately after graduation. Others, after graduate or professional school, went into academic philosophy, law, medicine, urban planning, and corporate management.

The philosophy faculty emphasizes interaction with students. Students participate with faculty members in "reading parties" each spring—retreats where students and faculty read and discuss ideas together for a few days. They attend lectures by distinguished philosophers who visit the campus two to three times each semester and participate in discussions with students. They join the Philosophy Club which brings students and faculty together in small group activity once a week.

Department honors are awarded on the basis of a thesis or a disputation (a public defense of a philosophical thesis or theses) supervised by one or more members of the department, and the attainment of a cumulative average for all courses in philosophy of 3.25 or better at the time of graduation.

## *The Minor Program*

The minor in philosophy consists of fifteen credit hours of course work. The specific courses to be taken by a student in this program are decided jointly by the student and the departmental adviser. These ordinarily include at least one course at the introductory level and one at the advanced level. Minor programs may be either of a general character or organized around a special theme such as: the philosophy of science, logic, ethics and value theory, the history of philosophy, and social philosophy.

## *The Major Program*

The major in philosophy consists of thirty credit hours of course work. The specific courses to be taken are decided jointly by the student and the departmental adviser. All major programs include the following:

| | |
|---|---|
| Phil 14 | Foundations of Logic (3) |
| Phil 131 | Ancient Philosophy (3) |
| Phil 135 | Modern Philosophy (3) |
| Phil 291 | Seminar (3) |

In addition to one of the following:

| | |
|---|---|
| Phil 15 | Ethics (3) |
| Phil 215 | Contemporary Ethics (3) |

Plus one of the following:

| | |
|---|---|
| Phil 128 | Philosophy of Science (3) |
| Phil 220 | Knowledge and Justification (3) |
| Phil 228 | Topics in the Philosophy of Science (3) |

All major programs must include at least three courses numbered 200 and above and no more than three courses numbered 100 and below. At the discretion of the department, a major may be required to take and pass English 171, Practical Writing.

## Undergraduate Courses

**1. The Great Conversation I (3)** fall
An introduction to philosophy by way of its history. The development of ideas about the real, the true, and the good in ancient and medieval times. Special attention to Plato, Aristotle, and Augustine. (May be taken independently of Phil 2). Melchert

**2. The Great Conversation II (3)** spring
An introduction to philosophy by way of its history. The struggle for wisdom since the development of modern science. What we can know, what we should do, and what kind of beings we are. (May be taken independently of Phil 1). Melchert

**10. Introduction to Philosophy (3)** fall-spring
Basic philosophical questions, perennial and contemporary, such as the objectivity of morals, the justification of government, the place of mind and feeling in the world of matter and energy, the nature of knowledge and truth, and the reality of God.

**13. Practical Logic (3)** fall
The role of logic in problem solving and decision-making processes. Comparison of deductive and inductive reasoning and justification. Practice in analysis, criticism, evaluation and construction of arguments. Emphasis on material drawn from real-life contexts. Barnes

**14. Foundations of Logic (3)** spring
Symbolic languages as theoretical models of logical features of English discourse, such as necessary truth and valid inference. Construction of logical proofs.

**15. Ethics (3)** fall-spring
Development of the ability to thoughtfully formulate one's own moral orientation and to understand those of others through a critical study of major ethical theories.

**114. (MS 114) War, Morality, Ethics and Military Professionalism (3)** spring
Development of the Profession of Arms, its fundamental values and institutions. Ethical responsibilities of military professionals in contemporary American society. Moral dimensions of war, just war theory and international law of war. Prerequisite: consent of department chairperson. Hare

**115. Business Ethics (3)** spring
Special problems in moral responsibility and ethical theory relating to contemporary business institutions, due to new dimensions of knowledge and evaluation, and emerging techniques of decision-making, planning, and management that characterize those institutions.

**116. Medical Ethics (3)** spring
Contemporary moral problems encountered in the practice of medicine examined in the light of ethical theories of the nature and foundation of rights and moral obligations. Abortion, euthanasia, genetic engineering, the nature of informed consent, the distribution of health care, etc.

**117. Engineering Ethics**
Contemporary moral problems encountered in the practice of engineering examined in the light of ethical theories of the nature of rights and obligation. Such issues as public policy making for engineering; obligations to employers, peers and the public; whistleblowing; codes of ethics and enforcement; professionalism. Dillon

**122. Philosophy of Law (3)** spring
Analysis of the conceptual foundations of our legal system. Special attention is devoted to the nature and validity of law, the concepts of liberty and justice in constitutional litigation, the theories of punishment in criminal law, and the nature and scope of responsibility in criminal law. Lindgren

**123. Aesthetics (3)** spring
Theories, classical and modern, of the nature of beauty and the aesthetic experience. Practical criticism of some works of art, and examination of analogies between arts, and between art and nature. Hare

**124. (Rel 124) Reason and Religious Experience (3)** spring
A critical look at some of the fundamental problems of religion: the nature of religious experience and belief, reason and revelation, the existence and nature of God, the problem of evil, and religious truth. Hare

**128. Philosophy of Science (3)** fall
Introduction to the structure and methods of scientific investigation. The nature of explanation, confirmation, and falsification. Scientific progress: What is it? Would it be suffocated by obedience to completely rational methods? Bearn

**131. (Clss 131) Ancient Philosophy (3)** fall
Historical study of philosophy in the classical world from the pre-Socratics to Plato, Aristotle, and the Neo-Platonists, as the originators of the western tradition in philosophy and as interacting with the religious, political and scientific life of their times. Hare

**133. Medieval Philosophy (3)** spring
Historical study of philosophy from the Roman Empire to the Renaissance. Attention to Islamic, Jewish, and Christian traditions and their interaction with the scientific and cultural life of the period. Goldman

**135. Modern Philosophy (3)**
Philosophers from the Renaissance through the end of the 19th century: Descartes, Locke, Hume, Rousseau, Kant and Hegel. Lindgren

**139. Contemporary Philosophy (3)**
Philosophical thought from the mid-19th century to the present; pragmatism, linguistic analysis, existentialism, and Marxism. Truth and knowledge, values and moral judgment, meaning, and place of the individual in the physical world and society, and the impact of scientific method upon all of these. Melchert

**214. Logical Theory (3)**
Conceptual foundations and philosophical significance of logical theories. Syntactic and semantic methods in logic, and their interrelations. Philosophical impact of important technical results, including Goedel's incompleteness theorem. Some discussion of alternative logics. Prerequisite: Phil 14 or consent of the department chairperson. Barnes

**215. Contemporary Ethics (3)** fall
Recent literature on problems in theoretical ethics. Prerequisite: Phil 15 or consent of the department chairperson.

**220. Knowledge and Justification (3)**
Recent work in epistemology. Questions addressed include: If you can't know whether you are dreaming, how can you know you have two hands? Does knowledge require answers to all possible doubts or only all reasonable doubts? How should we determine the horizon of the reasonable—psychologically or philosophically? Bearn

**221. (Law 221) Sex-Discrimination and the Law (3)** fall
A critical study of the law of sex-discrimination in areas of constitutional law, labor law, family law and criminal law. A case approach that places special emphasis on the rights of employees and the obligations of employers. Topics include equal protection, equal employment opportunity, affirmative action, and reproductive rights. Lindgren

**224. (Rel 224) Topics in the Philosophy of Religion (3)**
Selected problems and issues in the philosophy of religion. May be repeated for credit as the subject matter varies. Prerequisite: Phil 124 or consent of the department chairperson.

**228. Topics in the Philosophy of Science (3)**
Themes in the natural, life and social sciences. May be repeated for credit as topic varies. Prerequisite: Phil 128 or consent of the department chairperson. Goldman

**237. (Rel 237) Kierkegaard and Nietzsche (3)** spring
Two maverick thinkers of the 19th century, concerned with religious faith, values, and the meaning of human existence. Melchert

**250. The Minds of Men and Robots (3)** fall
Is the nature of thinking illuminated by what computers can do? Is the brain just a complex computer? Could a robot feel pain? Be angry? Recent work in artificial intelligence, psychology, and philosophy. Melchert

**251. Action, Free Will, and Fate (3)** spring
Are we free to act as we choose? Are we free to choose? The concept of action: intentions and actions, reasons and causes, and whether there can be deterministic explanations of actions. Prerequisite: one previous course in philosophy (except 13, 221). Melchert

**271. Readings in Philosophy (1-3)**
A course in readings designed primarily for the undergraduate philosophy majors and minors and graduate students in other disciplines. Prerequisite: consent of the department chairperson.

**272. Readings in Philosophy (1-3)**
A course of readings designed primarily for undergraduate philosophy majors and minors and graduate students in other disciplines. Prerequisite: consent of the department chairperson.

**291. Seminar (3)**
Examination of selected topics for philosophy majors and minors and other advanced students.

# Physics

**Professors.** W. Beall Fowler, Ph.D. (Rochester), *acting chairperson;* Garold J. Borse, Ph.D. (Virginia), *associate chairperson;* Robert T. Folk, Ph.D. (Lehigh); James D. Gunton, Ph.D. (Stanford), *Dean of the College of Arts and Science;* Alvin S. Kanofsky, Ph.D. (Pennsylvania); Yong W. Kim, Ph.D. (Michigan); James A. McLennan, Ph.D. (Lehigh); Shelden H. Radin, Ph.D. (Yale); Wesley R. Smith, Ph.D. (Princeton); George D. Watkins, Ph.D. (Harvard), *Sherman Fairchild Professor of Solid-State Studies.*
**Associate professors.** Brent W. Benson, Ph.D. (Penn State); Gary G. DeLeo, Ph.D. (Connecticut); Russell A. Shaffer, Ph.D. (Johns Hopkins); Michael Stavola, Ph.D. (Rochester).
**Assistant professors.** Daniel C. Hong, Ph.D. (Boston Univ.); John P. Huennekens, Ph.D. (Colorado); Jerome C. Licini, Ph.D. (M.I.T.); H. Daniel Ou-Yang, Ph.D. (U.C.L.A.); Ricardo A. Pakula, Ph.D. (Münich); Jean Toulouse, Ph.D. (Columbia).

Effective July 1, 1987, the department of physics, traditionally associated with the College of Engineering, became part of the College of Arts and Science. Because the change is primarily related to the university's organization, students enrolled in existing physics degree programs will not be affected in their course work.

Lehigh offers four undergraduate degrees in physics: the Bachelor of Science in Physics or the Bachelor of Arts in Physics in the College of Arts and Sciences, and the Bachelor of Engineering Physics or combined five year program for the Bachelor of Science in Electrical Engineering and Engineering Physics in the College of Engineering and Applied Science.

(The B.S. in E.E.E.P. is described on p. 37).

The two bachelor of science curricula require somewhat more physics and mathematics than the bachelor of arts major, while the latter requires more courses in the humanities, social sciences, and

foreign languages or cultures. By proper choice of electives, any of these programs can prepare a student for graduate work in physics or the physical aspects of other sciences or engineering disciplines, or can prepare for technical careers requiring a basic knowledge of physics. The bachelor of arts curriculum is particularly useful for those planning careers in areas where knowledge of physics is needed or useful, but is not the main subject, such as science writing, secondary school teaching, patent law, or medicine.

A comparison of the three curricula in terms of credit hours in various broad categories is given below.

| | Engineering College | College of Arts and Science | |
|---|---|---|---|
| | B.S.E.P. | B.S. | B.A. |
| Freshman English | 6 | 6 | 6 |
| Distribution Courses* | 19 | 19 | 33-41** |
| Required preliminary and major courses | 68 | 68 | 60 |
| Approved Electives | 14 | 14 | 11 |
| Electives | 20 | 19 | 3-11 |
| Total | 127 | 126 | 121 |

*Not including mathematics or science
**Depending on language requirements

A student in physics studies the basic laws of mechanics, heat and thermodynamics, electricity and magnetism, optics, relativity, quantum mechanics, and elementary particles. The student also studies applications of the basic theories to the description of bulk matter, including the mechanical, electric, magnetic, and thermal properties of solids, liquids, gases, and plasmas, and to the description of the structure of atoms and nuclei. In addition, the student develops the laboratory skills and techniques of the experimental physicist, skills that can be applied in the experimental search for new knowledge or in applications of the known theories.

Because of the fundamental nature of physics, students may use the major to prepare for many different careers. With judicious choice of electives, the physics student can prepare for graduate work in physics, in applied mathematics, in computer science, or in allied sciences such as biophysics, molecular biology, astrophysics, geophysics, materials engineering, meteorology, or physical oceanography. Further study toward careers in professional areas such as law or medicine is not uncommon.

In addition, the student may choose electives that prepare him or her for graduate work in those areas of engineering that have a high science content such as: aeronautical engineering; nuclear engineering, including both fission and fusion devices; electrical engineering, including instrumentation, electronics, and solid-state devices, electrical discharges and other plasma-related areas; and mechanical engineering and mechanics, including fluids and continuum mechanics. Graduate work in any of these areas can prepare the student for a career in industrial research or development, or in university or college teaching and research.

The student who plans on employment immediately after the bachelor's degree may choose electives that develop the skills needed for a position in a particular area. For example, by combining various electrical engineering courses with physics courses in electronics and solid-state physics, a strong applied background can be developed for employment in solid-state electronics. If the student chooses applied mathematics courses and computer courses to supplement the physics courses, a strong preparation can be achieved for employment in the many areas that use numerical methods in analysis and development.

Many other specialties may be developed by the student by appropriate use of electives so that the bachelor-degree student can offer an employer the advantages of a broad and fundamental science background combined with a significant concentration in a particular area of science, engineering, or applied mathematics.

Students are advised that admission to graduate school requires a minimum grade average, with a minimum average of B being typical.

**The recommended sequences of courses for the three degrees are:**

| B.A. (A.&S. Coll.) | | B.S. (A.&S. Coll.) | | B.S.E.P. (Engr. Coll.) | |
|---|---|---|---|---|---|
| Freshman Year | | | | | |
| FALL Semester | | | | | |
| Frshmn Englsh | (3) | Frshmn Englsh | (3) | Frshmn Englsh | (3) |
| Phys 11 (Lec) | (4) | Phys 11 (Lec) | (4) | Phys 11 (Lec) | (4) |
| Phys 12 (Lab) | (1) | Phys 12 (Lab) | (1) | Phys 12(Lab) | (1) |
| Math 21 | (4) | Math 21 | (4) | Math 21 | (4) |
| Gen. Skills | (3) | Distrib. Req. | (3) | Gen. Studies | (3) |
| A+S I | (1) | A+S I | (1) | | |
| | [16] | | [16] | | [15] |
| SPRING Semester | | | | | |
| Frshmn Englsh | (3) | Frshmn Englsh | (3) | Frshmn Englsh | (3) |
| Chem 21 (Lec) | (4) | Chem 21 (Lec) | (4) | Chem 21 (Lec) | (4) |
| Chem 22 (Lab) | (1) | Chem 22 (Lab) | (1) | Chem 22 (Lab) | (1) |
| Math 22 | (4) | Math 22 | (4) | Math 22 | (4) |
| Gen. Skills | (3) | *Engr I | (3) | Engr I | (3) |
| | [15] | | [15] | | [15] |
| Sophomore Year | | | | | |
| FALL Semester | | | | | |
| Phys 21 (Lec) | (4) | Phys 21 (Lec) | (4) | Phys 21 (Lec) | (4) |
| Phys 22 (Lab) | (1) | Phys 22 (Lab) | (1) | Phys 22 (Lab) | (1) |
| Math 23 | (4) | Math 23 | (4) | Math 23 | (4) |
| Dist. Req. | (6) | Dist. Req. | (3) | Eco 1 | (4) |
| | | Approved Elec | (3) | Elective | (3) |
| | [15] | | [15] | | [16] |
| SPRING Semester | | | | | |
| Phys 31 | (3) | Phys 31 | (3) | Phys 31 | (3) |
| Phys 190 | (3) | Phys 190 | (3) | Phys 190 | (3) |
| Math 205 | (3) | Math 205 | (3) | Math 205 | (3) |
| Dist. Req. | (6) | Dist. Req. | (3) | Gen. Studies | (3) |
| | | Electives | (4) | Elective | (3) |
| | [15] | | [16] | | [15] |
| Junior Year | | | | | |
| FALL Semester | | | | | |
| Phys 212 | (3) | Phys 212 | (3) | Phys 212 | (3) |
| Phys 215 | (3) | Phys 215 | (3) | Phys 215 | (3) |
| Phys 260** | (0-2) | Phys 260 | (2) | Phys 260 | (2) |
| Math 322 | (3) | Math 322 | (3) | Math 322 | (3) |
| Dist. Req. | (6) | Dist. Req. | (3) | Electives | (6) |
| | | Elective | (3) | | |
| | [15-17] | | [17] | | [17] |
| SPRING Semester | | | | | |
| Phys 213 | (3) | Phys 213 | (3) | Phys 213 | (3) |
| Phys 261** | (2-0) | Phys 261 | (2) | Phys 261 | (2) |
| Phys 362 | (3) | Phys 362 | (3) | Phys 362 | (3) |
| Dist. Req. | (8) | Phys 264 | (3) | Phys 264 | (3) |
| | | Dist. Req. | (3) | Gen. Studies | (3) |
| | | Elective | (3) | Elective | (3) |
| | [16-14] | | [17] | | [17] |
| Senior Year | | | | | |
| FALL Semester | | | | | |
| Phys 340 | (3) | Phys 340 | (3) | Phys 340 | (3) |
| Dist. Req. | (6) | Phys 216 | (3) | Phys 216 | (3) |
| Appr. Elec. | (5) | Dist. Req. | (3) | Gen. Studies | (3) |
| | | Electives | (6) | Electives | (8) |
| | [14] | | [15] | | [17] |
| SPRING Semester | | | | | |
| Phys 171 | (1) | Phys 171 | (1) | Phys 171 | (1) |
| Appr. Elec. | (6) | Electives | (14) | Gen. Studies | (3) |
| Electives | (8) | | | Electives | (11) |
| | [15] | | [15] | | [15] |
| | [121] | | [126] | | [127] |

*or an equivalent course in scientific computing
**only one of the two lab courses (PH260/1) is required for the B.A.

The electives include at least fourteen credit hours for Bachelor of Science degrees and eleven credit hours for the Bachelor of Arts degree of approved technical electives. Included in this group must be two of the following courses: Phys 363, 369, (352 or 355), and (346 or 348 or 365). Students planning graduate work in physics are advised to include Phys 273 and 369 among their electives. Up to 6 credit hours of the following courses may be included as part of the

credit hours required for graduation: Aerospace Studies, Jour 1-10, Military Science, and Mus 21-78.

**Special opportunities.** A majority of physics and engineering physics majors take advantage of opportunities to participate in research under the direction of a faculty member. Research areas available to undergraduates are the same as those available to graduate students; they are described below under the heading For Graduate Students. Undergraduate student research is arranged informally as early as the sophomore (or, occasionally, freshman) year at the initiation of the student or formally as a senior research project. In addition, a number of students receive financial support to do research during the summer between their junior and senior years, either as Physics Department Summer Research Participants or as Sherman Fairchild Scholars.

**The use of electives.** The electives provided in both physics curricula provide the student with an opportunity to develop special interests and to prepare for graduate work in various allied areas. The student is urged to reflect upon how to take advantage of this opportunity. A student contemplating graduate work in physics should consider the many upper-level physics and mathematics courses available, as well as some of the beginning graduate courses. In addition, note that some graduate schools require a reading knowledge of a modern foreign language.

Students contemplating using electives to develop a special area of interest should try to plan such a program as soon as possible by consultation with members of the faculty. Since many possibilities exist, it is impractical to list all such programs. Instead, two such programs are listed below to serve as guides for those with interests in those areas and to serve as models for those interested in developing their own programs in other areas.

### *Biophysics*

| | |
|---|---|
| Biol 21 | Principles of Biology (3) |
| Biol 28 | Mendelian and Population Genetics (3) |
| Biol 220 | Cell Physiology (3) |
| Biol 235 | Microbiology (3) |
| Biol 345 | Molecular Genetics (3) |
| Chem 51, 52 | Organic Chemistry (6) |
| Chem 371 | Elements of Biochemistry I (3) |

### *Solid-State Electronics*

| | |
|---|---|
| Mat 93 | Introduction to Solid State Materials (3) |
| ECE 125 | Circuits and Systems (3) |
| ECE 126 | Physical Electronics (3) |
| ECE 123 | Electronic Circuits (3) |
| ECE 308 | Device Electronics for Integrated Circuits (3) |
| ECE 351 | Microelectronics (3) |
| Phys 363 | Physics of Solids (3) |

## Undergraduate Courses in Physics

**9. Introductory Heat and Thermodynamics (1)** fall-spring
Temperature, heat, and the laws of thermodynamics; kinetic theory of gases. The student will be scheduled for the appropriate part of Phys 11. Prerequisites: three credit hours of advanced placement, anticipatory exam, or transfer credit for the mechanics part of Phys 11, and consent of the chairperson of the department.

**11. Introductory Physics I (4)** fall-spring
Kinematics, frames of reference, laws of motion in Newtonian theory and in special relativity, conservation laws, as applied to the mechanics of mass points; temperature, heat and the laws of thermodynamics; kinetic theory of gases. Two lectures and two recitations per week. Prerequisite: Math 21, 31 or 41, previously or concurrently. Borse or Benson

**12. Introductory Physics Laboratory I (1)** fall-spring
A laboratory course taken concurrently with Phys 11. Experiments in mechanics, heat, and DC electrical circuits. One three-hour laboratory period per week.

**13. General Physics (3)** spring
A continuation of Phys 11, primarily for students in the College of Arts and Science and premedical students. Electrostatics, electromagnetism, light, atomic physics, nuclear physics and radioactivity, introduction to biophysics. Prerequisites: Phys 11 and Math 21, 31 or 41. Radin

**14. General Physics Laboratory (1)** spring
A laboratory course to be taken concurrently with Phys 13. Prerequisite: Phys 12; Phys 13, preferably concurrently.

**19. Introductory Optics and Modern Physics (1)** fall-spring
Physical and geometrical optics; introduction to modern physics. The student will be scheduled for the appropriate part of Phys 21. Prerequisites: three credit hours of advanced placement, anticipatory exam, or transfer credit for the electricity and magnetism part of Phys 21, and consent of the chairperson of the department.

**21. Introductory Physics II (4)** fall-spring
A continuation of Phys 11. Electrostatics and magnetostatics; DC circuits; Maxwell's equations; waves; physical and geometrical optics; introduction to modern physics. Two lectures and two recitations per week. Prerequisite: Phys 11; Math 23, 32, or 44, previously or concurrently. DeLeo or McLennan

**22. Introductory Physics Laboratory II (1)** fall-spring
A laboratory course to be taken concurrently with Phys 21. One three-hour laboratory period per week. Prerequisite: Phys 12; Phys 21, preferably concurrently.

**31. Introduction to Quantum Mechanics (3)** fall-spring
Experimental basis and historical development of quantum mechanics; the Schroedinger equation; one-dimensional problems; angular momentum and the hydrogen atom; many-electron systems; spectra; selected applications. Three lectures per week. Prerequisite: Phys 13 or 21; Math 205, previously or concurrently. Toulouse, Watkins, DeLeo

**42. Physics for Poets (3)** spring
The principal concepts and discoveries of physics are presented in a concise manner. The purpose of the course is to provide students majoring in subjects other than science and engineering with sufficient background to enable them to appreciate physics and its impact on modern society. The laboratory serves to demonstrate the concepts covered in class and to provide some exposure to modern measurement devices and computers. High school physics is not assumed. Two recitations and one laboratory per week. No prerequisite. Fowler

**171. Physics Proseminar (1)** spring
Discussion of current problems in physics. Intended for seniors majoring in the field. Watkins

**190. Electronics (3)** spring
DC and AC circuits, diodes, transistors, operational amplifiers, oscillators, and digital circuitry. Two laboratories and one recitation per week. Prerequisites: Phys 21 and 22, or Phys 13 and 14. Smith

## For Advanced Undergraduates And Graduate Students

**212. Electricity and Magnetism I (3)** fall
Electrostatics, magnetostatics, and electromagnetic induction. Prerequisites: Phys 21 or 13; Math 205, previously or concurrently. Smith

**213. Electricity and Magnetism II (3)** spring
Maxwell's equations, Poynting's theorem, potentials, the wave equation, waves in vacuum and in materials, transmission and reflection at boundaries, guided waves, dispersion, electromagnetic field of moving charges, radiation, Lorentz invariance and other symmetries of Maxwell's equations. Prerequisite: Phys 212. Folk

**215. Classical Mechanics I (3)** fall
Kinematics and dynamics of point masses; force laws, including motion in a central force field, simple harmonic motion and

non-linear oscillations; conservation laws; description of a system of particles, including collisions; moving coordinate systems and the special theory of relativity. Prerequisites: Phys 21 or Phys 13 and Math 205, previously or concurrently. Shaffer

**216. Classical Mechanics II (3)** fall
Continuation of Phys 215. Gravitation; rotating coordinate systems; motions of rigid bodies; Lagrange's and Hamilton's equations; continuum mechanics, including elasticity and fluid mechanics. Prerequisite: Phys 215. Folk

**260. Laboratory Techniques (2)** fall
Laboratory practice, including machine shop, vacuum systems, electronic instrumentation, computers and integrated circuits, high-voltage measurements, counting and statistics. Prerequisites: Phys 21 and 22, or Phys 13 and 14. Ou-Yang

**261. Optics, Spectroscopy, and Quantum Physics Laboratory (2)** spring
Experiments in geometrical optics, interference and diffraction, spectroscopy, lasers, and quantum phenomena. Prerequisites: Phys 21 and 22, or Phys 13 and 14. Huennekens

**264. Nuclear and Elementary Particle Physics (3)** spring
Models, properties, and classification of nuclei and elementary particles; nuclear and elementary particle reactions and decays; radiation and particle detectors; accelerators; applications. Prerequisites: Phys 31 and Math 205. Shaffer

**273. Research (2-3)** fall-spring
Participation in current research projects being carried out within the department. Intended for seniors majoring in the field. May be repeated once for credit.

**281. Basic Physics I (3)** summer
A course designed especially for secondary-school teachers in the master teacher program. Presupposing a background of two semesters of college mathematics through differential and integral calculus and of two semesters of college physics, the principles of physics are presented with emphasis on their fundamental nature rather than on their applications. Open only to secondary-school teachers and those planning to undertake teaching of secondary-school physics.

**282. Basic Physics II (3)** summer
Continuation of Phys 281.

**312. Advanced Laboratory (1)** fall-spring
Experiments in modern physics designed to introduce students to measuring techniques and phenomena of current interest. Prerequisite: senior or graduate standing in the field, or consent of the department chairperson. May be repeated for credit.

**340. Thermal Physics (3)** fall
Basic principles of thermodynamics, kinetic theory, and statistical mechanics, with emphasis on applications to classical and quantum mechanical physical systems. Prerequisites: Phys 13 or 21, and Math 23, 32 or 44. Pakula

**346. Physics of Developing Energy Sources (3)** spring
Basic concepts, theoretical development, and experimental techniques pertaining to developing energy sources. Topics include thermonuclear, magnetohydrodynamic, solar and other potential sources of energy. Prerequisite: senior standing in the College of Engineering and Applied Sciences, or consent of the department chairperson.

**348. Plasma Physics (3)** spring
Single particle behavior in electric and magnetic fields, plasmas as fluids, waves in plasmas, transport properties, kinetic theory of plasmas, controlled thermonuclear fusion devices. Prerequisites: Phys 21, Math 205, and senior standing or consent of the chairman of the department. Pakula

**352. Modern Optics (3)** spring
Paraxial optics, wave and vectorial theory of light, coherence and interference, diffraction, crystal optics, and lasers. Prerequisites: Math 205, and Phys 212 or ECE 202. Toulouse

**355. Lasers and Non-linear Optics (3)** fall
Basic principles and selected applications of lasers and non-linear optics. Topics include electromagnetic theory of optical beams, optical resonators, laser oscillation, non-linear interaction of radiation with atomic systems, electro- and acousto-optics, optical noise, optical waveguides, and laser devices. Prerequisites: Phys 31; Phys 213 or ECE 203, previously or concurrently. Radin

**362. Atomic and Molecular Structure (3)** spring
Review of quantum mechanical treatment of one-electron atoms, electron spin and fine structure, multi-electron atoms, Pauli principle, Zeeman and Stark effects, hyperfine structure, structure and spectra of simple molecules. Prerequisite: Phys 31 or Chem 341. Licini

**363. Physics of Solids (3)** fall
Introduction to the theory of solids with particular reference to the physics of metals and semiconductors. Prerequisite: Phys 31 or Mat 316 or Chem 341. Benson

**365. Physics of Fluids (3)** spring
Concepts of fluid dynamics; continuum and molecular approaches; waves, shocks and nozzle flows; nature of turbulence; experimental methods of study. Prerequisites: Phys 212 or ECE 202, and Phys 340 or ME 104 or equivalent, previously or concurrently.

**369. Quantum Mechanics I (3)** fall
Principles of quantum mechanics: Schroedinger, Heisenberg, and Dirac formulations. Applications to simple problems. Prerequisites: Phys 31, Math 205; Phys 216, previously or concurrently. Watkins

**372. Special Topics in Physics (1-3)**
Special topics in physics not sufficiently covered in the general courses. Lecture and recitations or conferences.

**382. Applied Solid State Physics (3)** spring
Applications of fundamental solid state physics to topics of current interest with emphasis on various physical effects and their use in practical applications. Topics include: effects of barriers and applied potentials on band structure (semiconductor junctions and interfaces), luminescence and photon absorption (solid-state lasers and radiation detectors), ferroelectricity and dielectric phenomena (electro-optical communication), superconductivity (Josephson and quantum interference devices). Prerequisite: Phys 363, or consent of the chairman of the department.

## For Graduate Students

The department of physics has concentrated its research activities within several fields of physics, with the result that a number of projects are available in each area. Current departmental research activities include the following:

**Solid-state physics (experimental).** Optical and electronic properties of defects in semiconductors and insulators, electron paramagnetic resonance, ultrasonic attenuation, Raman spectroscopy, luminescence spectroscopy. Properties of thin films, physics of semiconductor devices.

**Solid-state physics (theoretical).** Electronic properties of defects in semiconductors and insulators, electronic structures, electron-lattice interactions, energy band calculations.

**Atomic and molecular physics.** Electron attachment. Optically assisted reactions. Collisional phenomena in alkali metal vapors.

**Plasma spectroscopy.** Collisional and collisionless phenomena of very dense plasmas. Laser-produced plasmas.

**Nuclear theory.** The few nucleon problem, nuclear structure theory.

**Physics of fluids.** Microscopic fluctuations in a flow. Shock-induced reactions in gases and phase transitions at liquid-vapor interfaces. Small particle dynamics. Light-scattering spectroscopy.

**Statistical physics (experimental).** Non-equilibrium fluctuations in gases. Chaotic transitions. Colloidal suspensions and complex fluids. Disordered materials.

**Statistical physics (theoretical).** Kinetic theory, statistical basis

of hydrodynamics, non-linear processes, bound states and internal degrees of freedom in kinetic theory. Study of pattern formation in dendritic growth.

**Elementary particles (experimental).** Fermilab and Brookhaven are used in channeling, device development, and particle jet studies.

**Elementary particles (theoretical).** Properties of leptons and vector bosons, weak and electromagnetic interactions. Quark-Glauber calculations of elastic and inelastic scattering.

**Non-linear optics.** Theoretical and experimental work in lasers and non-linear optics.

**Van de Graaff studies.** Experiments to study nuclear reactions, channeling, new instrumentation techniques, Rutherford back-scattering using the Lehigh van de Graaff accelerator.

Candidates for advanced degrees normally will have completed, before beginning their graduate studies, the requirements for a bachelor's degree with a major in physics, including advanced mathematics beyond differential and integral calculus. Students lacking the equivalent of this preparation will make up deficiencies in addition to taking the specified work for the degree sought.

Doctoral candidates may be required by their thesis committee to demonstrate a reading knowledge of one language, usually chosen from French, German or Russian. Some graduate work in mathematics is usually required; and certain advanced courses in other fields, notably mechanics, metallurgy and materials engineering, electrical engineering, and chemistry, may be included in a graduate program. Further details regarding the special requirements for degrees in physics may be obtained on application to the department chairperson.

At least eight semester hours of general college physics using calculus are required for admission to all 200- and 300-level courses. Additional prerequisites for individual courses are noted in the course descriptions. Admission to 400-level courses generally is predicated on satisfactory completion of corresponding courses in the 200- and 300-level groups or their equivalent.

**Facilities for Research.** The 1985-86 renovation and addition to the Physics Building has made available many new research laboratories and improved the quality of the older research space. It also expanded the shop area and provided a direct connection to the Sherman Fairchild Laboratory, where solid-state physics faculty and research space are located.

Among the research equipment available in the various experimental physics laboratories are: three electron spin resonance laboratories; a laboratory for optical detection of magnetic resonance; facilities for optical absorption and luminescence studies; ultraviolet, visible, and infrared spectrophotometers; liquid nitrogen, hydrogen, and helium cryogenic equipment; several shock tubes; film scanning apparatus; cosmic ray detectors; 9 high-power lasers (4 argon-ion lasers, 2 tunable pulsed dye lasers, a ruby laser, and 2 mode-locked, Q-switched Nd-glass lasers); crystal-growing facilities; a mass-spectrometer, large interferometers, an electron microscope, a high-density plasma source; electronic instrumentation for data acquisition and analysis, including several minicomputers, many microcomputers, and signal averagers.

A 3 MeV Van de Graaff accelerator housed in the Sherman Fairchild Laboratory is used to study radiation defects in solids, to analyze impurity distributions in thin films, to develop instrumentation, and to study channeling and nuclear physics. Also available in materials and electrical engineering laboratories in the Fairchild Laboratory are excellent facilities for the preparation of solid-state materials and the fabrication of solid-state devices; these facilities are heavily used by physics students doing experimental solid-state research.

## Graduate Courses in Physics

**420. Theoretical Physics (3)** fall
This and the three courses Phys 421, 422, and 423 cover the classical theory of particles and fields. Phys 420 includes the variational methods of classical mechanics, methods of Hamilton and Lagrange, canonical transformations, Hamilton-Jacobi theory. Fowler

**421. Theoretical Physics (3)** spring
Theory of elasticity; fluid dynamics; tensor analysis; electrostatics and magnetostatics. Prerequisite: Phys 420. Ou-Yang

**422. Advanced Theoretical Physics (3)** fall
Electromagnetic radiation; dynamics of charged particles; multipole fields; special theory of relativity and covariant formulation of electrodynamics. Prerequisite: Phys 421. Licini

**423. Advanced Theoretical Physics (3)**
Electrodynamics in anisotropic media; physical optics; theory of diffraction and application to holography; applications of electrodynamics. Prerequisite: Phys 422.

**424. Quantum Mechanics II (3)** spring
General principles of quantum theory; approximation methods; spectra; symmetry laws; theory of scattering. Prerequisite: Phys 369 or equivalent. Hong

**425. Quantum Mechanics III (3)** fall, even-numbered years
A continuation of Phys 424. Relativistic quantum theory of the electron; theory of radiation. McLennan

**428. Methods of Mathematical Physics (3)** fall
The equations of theoretical physics and the methods of their solution. Borse

**429. Methods of Mathematical Physics (3)** spring
Continuation of Phys 428. Borse

**431. Theory of Solids (3)** spring, even-numbered years
Advanced topics in the theory of the electronic structure of solids. Many-electron theory. Theory of transport phenomena. Magnetic properties, optical properties. Superconductivity. Point imperfections. Prerequisite: Phys 363 and Phys 424. DeLeo

**434. Solids and Radiation (3)**
Phenomena in solids resulting from interaction with electromagnetic radiation or charged particles. Current theories of energy absorption, transport and emission. Prerequisite: Phys 363 or equivalent.

**442. Statistical Mechanics (3)** fall
General principles of statistical mechanics with application to thermodynamics and the equilibrium properties of matter. Prerequisite: Phys 340 and 369. Kim

**443. Nonequilibrium Statistical Mechanics (3)** spring, odd-numbered years
A continuation of Phys 442. Applications of kinetic theory and statistical mechanics to nonequilibrium processes; non-equilibrium thermodynamics. Prerequisite: Phys 442. McLennan

**446. Atomic and Molecular Physics (3)**
Advanced topics in the experimental and theoretical study of atomic and molecular structure. Topics include fine and hyperfine structure, Zeeman effect, interaction of light with matter, multi-electron atoms, molecular spectroscopy, spectral line broadening atom-atom and electron-atom collisions and modern experimental techniques. Prerequisite: Phys 424 or consent of the instructor.

**462. Theories of Elementary Particle Interactions (3)**
Relativistic quantum theory with applications to the strong, electromagnetic and weak interactions of elementary particles. Prerequisite: Phys 425. Shaffer

**465. Nuclear and Elementary Particle Physics (3)** fall, even-numbered years
Nuclear structure and phenomena; interactions among elementary particles and methods of studying them. Kanofsky

**467. Nuclear Theory (3)** spring, odd numbered years
Theory of low-energy nuclear phenomena within the framework of nonrelativistic quantum mechanics. Borse

**471. (Mech 411) Continuum Mechanics (3)**
An introduction to the continuum theories of the mechanics of solids and fluids. This includes a discussion of the mechanical and thermodynamical bases of the subject, as well as the use of invariance principles in formulating constitutive equations. Applications of theories to specific problems are given. G. Smith, Varley

**472. Special Topics in Physics (1-3)**
Selected topics not sufficiently covered in the more general courses. May be repeated for credit.

**474. Seminar in Modern Physics (3)**
Discussion of important advances in experimental physics. May be repeated for credit when a different topic is offered.

**475. Seminar in Modern Physics (3)**
Discussion of important advances in theoretical physics. May be repeated for credit when a different topic is offered.

**491. Research (3)**
Research problems in experimental or theoretical physics.

**492. Research (3)**
Continuation of Phys 491. May be repeated for credit.

# Portuguese

See listings under Modern Foreign Languages.

# Psychology

**Professors.** Arthur L. Brody, Ph.D. (Indiana); Donald T. Campbell, Ph.D. (Berkeley), *University Professor of Social Relations and Psychology;* Martin L. Richter, Ph.D. (Indiana); George K. Shortess, Ph.D. (Brown); John G. Nyby, Ph.D. (Texas, Austin).
**Associate professors.** Diane T. Hyland, Ph.D. (Syracuse); William Newman, Ph.D. (Stanford), *chairperson;* Neal G. Simon, Ph.D. (Rutgers); S. Lloyd Williams, Ph.D. (Stanford).
**Assistant professors.** Susan Barrett, Ph.D. (Brown); Barbara C. Malt, Ph.D. (Stanford); Sandra L. Pipp, Ph.D. (Denver).
**Adjunct professors.** Ian Birky, Ph.D. (Oklahoma State); Roy C. Herrenkohl, Ph.D. (N.Y.U.); Murray Itzkowitz, Ph.D. (Maryland); Edwin J. Kay, Ph.D. (Lehigh); Theophile Krawiec, Ph.D. (N.Y.U.); Judith N. Lasker, Ph.D. (Harvard); John F. Riley, Ed.D. (Lehigh); Robert E. Rosenwein, Ph.D. (Michigan); Edward S. Shapiro, Ph.D. (Pittsburgh).
**Visiting assistant professor.** Craig Clarke, Ph.D. (Lehigh).

## *Major Program in Psychology*

The bachelor of arts in psychology is a social science major requiring a minimum of 34 credit hours in psychology as defined below. Second-semester freshmen who have completed Psych 1 or 11 can enroll in the 100-level courses by petition, and should check with the chairperson of the psychology department if interested.

## *Required Major Courses*

| | |
|---|---|
| Psyc 1 | Introduction to Psychology (3) **or** |
| Psyc 11 | Introduction to Psychology: Discussion Format (3) **and** |
| Psyc 110 | Experimental Design and Statistical Analysis (3) |
| Psyc 210 | Experimental Psychology (4) |

**Plus the following**
*one from each of the four categories*

| | |
|---|---|
| A) Psyc 107 | Child Development (3) |
| Psyc 108 | Adolescent Development (3) |
| Psyc 109 | Adulthood and Aging (3) |
| B) Psyc 21 | Social Psychology (3) |
| Psyc 154 | Introduction to Clinical Psychology (3) |
| C) Psyc 117 | Cognitive Psychology (3) |
| Psyc 171 | Learning (3) |
| D) Psyc 176 | Cognitive Neuroscience (3) |
| Psyc 177 | Introduction to Physiological Psychology (3) |

*and at least four from*

| | |
|---|---|
| Psyc 305 | Abnormal Psychology (3) |
| Psyc 307 | Seminar in Cognition (3) |
| Psyc 331 | Humanistic Psychology (3) |
| Psyc 351 | Cognitive Development in Childhood (3) |
| Psyc 353 | Personality Theory (3) |
| Psyc 354 | Personality Assessment (3) |
| Psyc 361 | Special Topics in Adult Development (3) |
| Psyc 363 | Social and Personality Development (3) |
| Psyc 371 | Theories of Learning (3) |
| Psyc 373 | Sensation and Perception (3) |
| Psyc 375 | Neuroanatomy of Behavior (3) |
| Psyc 382 | Endocrinology of Behavior (3) |

**Additional Required Courses.** These fulfill College of Arts and Science distribution requirements. They are elective courses that bring the credit-hour total to 121.

Note: Psychology majors may not use psychology courses to satisfy upperclass college distribution requirements.

## *Recommended Electives*

The bachelor of arts program in psychology is a flexible preparation for a number of fields. With a suitable selection of additional courses, students can prepare themselves for graduate study in clinical psychology, developmental psychology, social psychology, personality, or for careers in areas for which psychology is a desirable and relevant major, e.g., law, social work, nursing, or special education. Courses recommended, in addition to those major courses listed above are:

| | |
|---|---|
| Psyc 161 | Independent Research Seminar (1-3) |
| Psyc 162 | Psychological Field Work (1-3) |
| Psyc 395, 396 | Thesis (6) |
| Psyc 421, 422 | Analysis and Design of Experiments (6) (by petition) |
| Math 41 | BMSS Calculus I (3) |
| Biol 21 | Principles of Biology (3) |
| Biol 28 | Mendelian and Population Genetics (3) |

With greater emphasis on mathematics and science, the program provides preparation for graduate study in experimental psychology, medicine or dentistry. In this case, additional recommended courses are:

| | |
|---|---|
| Psyc 161 | Independent Research Seminar (1-3) |
| Psyc 162 | Psychological Field Work (1-3) |
| Psyc 374 | Sensation and Perception Laboratory (1) |
| Psyc 376 | Physiological Psychology Laboratory (1) |
| Psyc 395, 396 | Thesis (6) |
| Psyc 421, 422 | Analysis and Design of Experiments (6) (by petition) |
| Math 21, 22, 23 | Analytic Geometry and Calculus I, II and III (12) **or** |
| Math 31, 32 | Honors Calculus I and II (8) **or** |
| Math 41, 42, 43, 44 | BMSS Calculus I, Probability, Linear Algebra and Calculus II (12) |
| Biol 21, 22 | Principles of Biology and Laboratory (4) |
| Chem 21, 22 | Introductory Chemical Principles and Laboratory (5) |
| CSc 11 | Introduction to Structured Programming (3) |
| CSc 17 | Structured Programming and Data Structures (4) |
| Phys 11, 12 | Introductory Physics I and Laboratory (5) |
| Phil 128 | Philosophy of Science (3) |

plus additional electives in mathematics, probability, statistics, computing and information science, biology, chemistry, and physics.

All students planning to pursue graduate study in psychology should take:

| | |
|---|---|
| Psyc 395, 396 | Thesis (6) |

Of particular interest to those students interested in a career in business administration is the five-year Arts B.A.-M.B.A. degree. In this option, a student majors in psychology, takes requisite courses in the College of Business and Economics, and then takes an additional year of study in business administration beyond the bachelor's degree. The Arts B.A.-M.B.A. program is described in Section III. There are, of course, many other possibilities. Students interested in formulating a particular career-based program of study should consult the department chairperson.

## *Honors Program in Psychology*

The honors program in psychology permits psychology majors of unusual academic ability and interest to explore areas of psychology in greater depth than the curricula normally allow. Under faculty supervision, a student normally spends the first semester of the senior year doing library research, learning the appropriate methodology, and preparing a written proposal. In the second semester the proposal is implemented, culminating in a written honors thesis. Successful completion of this program results in "Departmental Honors" being affixed to the student's transcript.

Eligibility requirements. Eligible students must be psychology majors; have completed the first semester of the junior year with an over-all GPA of 3.0; and have completed a minimum of four psychology courses with a GPA of 3.3.

Interested students should contact the chairperson.

## *The Psychology Minor*

The psychology minor consists of fifteen credit hours in psychology beyond the introductory course (Psych 1, 21). At least one of these courses must be above the 200 level. The student should consult the department chairperson no later than the fifth semester regarding course selection.

## *Major Program in Behavioral and Neural Biology (BNB)*

Co-sponsored by the departments of psychology and biology and offering both B.A. and B.S. degrees, this major examines the physiology, genetics and evolution of behavior. An interdisciplinary program, BNB draws upon psychology, biology, chemistry and anthropology with an emphasis on the neurosciences. Additional math and science courses are necessary to round out these curricula.

## *B.A. in Behavioral and Neural Biology*

The B.A. in Behavioral and Neural Biology is a natural science major for B.A. distribution purposes.

## *Required Major Courses*

**Core Courses**

| | |
|---|---|
| Psyc 1 | Introduction to Psychology (3) **or** |
| Psyc 11 | Introduction to Psychology: Discussion Format (3) |
| Biol 21 | Principles of Biology (3) **and** |
| Biol 22 | Introduction to Biology Laboratory (1) |
| Anth 12 | Emergence of Mankind and Culture (3) |
| Biol 28 | Mendelian and Population Genetics (3) |
| Psyc 110 | Experimental Design and Statistical Analysis (3) |
| Psyc 210 | Experimental Psychology (4) |
| Psyc 177 | Introduction to Physiological Psychology (3) |

**Category 1: take one course**

| | |
|---|---|
| Biol/Psyc 335 | Animal Behavior (3) |
| Biol/Psyc 337 | Sociobiology (3) |

**Category 2: take one course**

| | |
|---|---|
| Psyc/Biol 375 | Neuroanatomy of Behavior (3) |
| Psyc 382/Biol 376 | Endocrinology of Behavior (3) |

**Category 3: nine credits (major electives)**

| | |
|---|---|
| Psyc 77 | Drugs and Behavior (3) |
| Psyc 154 | Introduction to Clinical Psychology (3) |
| Psyc 160 | Independent Study (1-3) |
| Psyc 161 | Independent Research Seminar (1-3) |
| Psyc 171 | Learning Processes and Applications (3) |
| Psyc 176 | Introduction to Cognitive Neuroscience (3) |
| Psyc 305 | Abnormal Psychology (3) |
| Psyc 353 | Personality Theory (3) |
| Psyc 371 | Theories of Learning (3) |
| Psyc 373 | Sensation and Perception (3) |
| Psyc 376 | Physiological Psychology Laboratory (1) |
| Psyc 377 | Seminar in Physiological Psychology (3) |
| Psyc/SR 345 | Seminar on the Social Evolution of Complex Organizations (3) |
| Biol 133 | Invertebrate Zoology (3) |
| Biol 134 | Comparative Vertebrate Anatomy (4) |
| Biol 151 | Vertebrate Field Biology (3) |
| Biol 211 | Ecology (3) |
| Biol 220 | Cell Physiology (3) |
| Biol 223 | Animal Physiology (3) |
| Biol 256 | Human Genetics and Reproduction (3) |
| Biol 309 | Aquatic Biology (3) |
| Biol 313 | General Histology (3) |
| Biol 314 | Developmental Biology (3) |
| Biol 317 | Evolution (3) |
| Biol 319 | Reproduction and Mating Systems (3) |
| Biol 336 | Animal Behavior Laboratory (2) |
| Biol 338 | Endocrinology/Reproductive Physiology (3) |
| Chem 371 | Elements of Biochemistry I (3) |
| Chem 372 | Elements of Biochemistry II (3) |
| Chem 377 | Biochemistry Laboratory (3) |

## *Required Courses in Math and Chemistry*

| | |
|---|---|
| Math 41, 44 | BMSS Calculus I and II (6) **or** |
| Math 21, 22 | Analytic Geometry and Calculus I and II (8) |
| Chem 21 | Introductory Chemical Principles (4) |
| Chem 22 | Chemical Principles Laboratory (1) |
| Chem 51, 52 | Organic Chemistry (6) |
| Chem 55 | Organic Chemistry Laboratory (2) |

## *Other Options*

The B.A. in Behavioral and Neural Biology is a traditional liberal arts degree which can be structured for a wide variety of possibilities (see listing of recommended elective courses). By using free electives to take additional math and science, the B.A. also can serve as a preprofessional degree for many graduate and professional schools. Students interested in a particular career-based program should consult their advisor or the program director (Professor John Nyby).

## *B.S. in Behavioral and Neural Biology*

B.S. majors would be required to take the core courses and *all* of the courses listed in category 1 and category 2 of the B.A. program and to fulfill the elective requirements of category 3 of the B.A. program. An early commitment to the B.S. is desirable to meet all the requirements of this program. Additional requirements are shown below.

**Math and science requirements for the B.S.**

| | |
|---|---|
| Math 21, 22, 23 | Analytic Geometry and Calculus I, II & III (12) |
| Chem 21, 22 | Introductory Chemical Principles & Lab (5) |
| Chem 51, 52 | Organic Chemistry I & II (6) |

| | |
|---|---|
| Chem 58 | Organic Chemistry Laboratory II (1) |
| Chem/Biol 371 & 372 | Elements of Biochemistry I & II (6) |
| Chem 377 | Biochemistry Laboratory (3) |
| Phys 11, 12 | Introductory Physics and Laboratory (5) |
| Phys 13, 14 | General Physics and Laboratory (4) |

Phys 21, 22 (5) can substitute for Phys 13, 14.

**University and College requirements for the B.S.**

| | |
|---|---|
| Engl 1 | Composition and Literature (3) |
| Engl 2, 4, 6, 8 or 10 | Composition and Literature (3) |
| Arts and science 1 | Choices and Decisions (1) |

Nonscience Electives (30) to be broadly distributed in fields of thought other than the natural sciences and mathematics, including at least 12 credit hours each in the humanities and social sciences.

## Undergraduate Courses

The entry NS or SS applies only to psychology courses and refers to Natural Science or Social Science distribution requirements. Note: Psychology majors may *not* use SS or NS psychology courses to satisfy the upper level social science or natural science distribution requirement. Some listings also state the semester in which the course is customarily offered.

**1. Introduction to Psychology (3)** NS SS fall-spring
Psychology as a science of behavior. Natural science aspects such as learning, sensation-perception, and physiological bases; and social science aspects such as human development, intelligence, and personality. Methodologies appropriate to these areas, and related societal problems.

**11. Introduction to Psychology: Discussion Format (3)** NS SS fall-spring
Identical in content to Psych 1 but classes are kept small.

**21. (SPsy 21) Social Psychology (3)** SS
Theories, methods of investigation, and results of research in social psychology with emphasis on psychological processes in social behavior, social attitudes, group behavior, and social interaction. Not offered to students who have had Soc Psych 7.

**31. Normal and Altered States of Consciousness (3)** SS
Normal and altered states of consciousness are defined. These include waking, sleep, meditation, madness, and drug states. Newman

**65. (Art 65) Perception and the Visual Arts (3)** NS fall
Perceptual and cognitive theories and principles as related to visual fine arts and aesthetic experience. Shortess

**77. Drugs and Behavior (3)** SS spring
Basic principles of drug action in the central nervous system. Effects of stimulants, depressants, intoxicants and drug abuse on behavioral function. Clinical use of drugs in the treatment of various psychological and psychiatric disorders. Simon, Newman

**81. Psychology and Law (3)** SS fall
Problems with the concepts of insanity, psychosis, and therapy; commitment procedures, incompetency, and the insanity defense; patient's rights; psychological tests, discrimination and privacy; school and family law problems; and the expert witness and confidentiality. Brody

**107. Child Development (3)** SS fall-spring
Survey of theories and research concerning perceptual, cognitive, social, and personality development through infancy and childhood. Prerequisite: Psyc 1 or 11. Pipp

**108. Adolescent development (3)** SS spring
Descriptions and explanations of cognitive, personality, and physical development during the adolescent and early adult years. The stresses of adolescence and the difficulties that individuals encounter in their initial attempts to function as adults. Prerequisite: Psyc 1 or 11. Pipp

**109. (SPsy 109) Adulthood and Aging: Social and Psychological Perspectives (3)** SS fall
Psychological, sociological and other social science approaches to the latter two-thirds of the life span. Age stratification and distribution patterns, attitudes of aging, social behavior of older adults, widowhood, issues of retirement and use of leisure time. Blank, Hyland

**110. Experimental Design and Statistical Analysis (3)** NS fall-spring
Principles of experimental design and statistical analysis: characteristics of data and data collection; descriptive statistics; hypothesis testing theory and practice; correlation, chi-square, t-test, analysis of variance. Richter, Brody

**115. History of Modern Psychology (3)** SS spring
Origin and development of major theories within perception, cognition, biological, clinical, personality, developmental, learning. Nineteenth and twentieth century thought to provide an overview of psychology as a discipline. Prerequisite: Psyc 1 or 11 or consent of the department chairperson.

**117. Cognitive Psychology (3)** NS spring
Information processing by human beings: attention, memory, language, and thought processes. Prerequisite: Psyc 1, 11 or CogS 101. Malt

**121. Encountering Self and Others (3)** SS spring
An experientially oriented course to facilitate personal growth and develop a fuller awareness of personal functioning and interpersonal perception and communication. Pass-fail grading. Prerequisite: consent of the department chairperson. Newman

**131. Psychology of Women (3)** SS fall
Biological, cross-cultural, sociological and psychological perspectives on women, with reference to personal experience where appropriate. Prerequisite: Psyc 1 or 11 or an introductory social relations course. Hyland

**154. Introduction to Clinical Psychology (3)** SS spring
Survey of clinical psychology as a science and profession. Current psychological treatment approaches, assessment techniques, research strategies, and their empirical and theoretical foundations. Training of clinical psychologists and ethical issues in clinical research and practice. Prerequisite Psych 1 or 11. Williams

**160. Independent Study (1-3)** NS SS fall-spring
Readings on topics selected in consultation with a staff member. Prerequisite: Psyc 1 or 11 and consent of the department chairperson. May be repeated for credit. Fulfills natural science or social science distribution requirements for students in the College of Arts and Science by petition only.

**161. Independent Research Seminar (1-3)** NS SS fall-spring
Individual research projects are designed and executed in close collaboration with the faculty. Students meet with the seminar director to communicate about and critique each other's projects. Prerequisite: Consent of the department chairperson. May be repeated for credit. Fulfills NS or SS distribution requirements for students in the College of Arts and Science by petition only.

**162. Psychological Field Work (1-3)** SS fall-spring
Work-Study practice including supervised experience in one of several local agencies. Development of familiarity with the operations of the agency and working with individual patients or students. Prerequisite: Psyc 1 or 11 plus two additional psychology courses and consent of instructor.

**171. Learning Processes and Applications (3)** NS fall
Experimental data on animal and human conditioning and learning. Applications to mental health, mental retardation, education. Prerequisite: Psyc 1 or 11. Brody, Richter

**176. Introduction to Cognitive Neuroscience (3)** NS spring
Neurophysiological correlates of human cognitive and emotional processes such as imaging, dreams, hallucinations, attention, memory and language. Emphasis on cerebral lateralization, sleep and effects of brain damage on mental processes. Prerequisite: Psyc 1 or 11. Shortess

**177. Introduction to Physiological Psychology (3)** NS fall
Nervous system functioning with varying emphasis on neurophysiology, neuroanatomy, behavior genetics, information transmission, research techniques, sensory and motor functions. Prerequisite: Psyc 1 or 11 or Biol 1 or 21. Shortess, Nyby, Simon

**201. Industrial Psychology (3)** SS fall
Psychological concepts and methods applied to business and industrial settings. Personnel selection, placement and training, leadership, work motivation, job satisfaction and consumer behavior. Prerequisite: Psyc 1 or 11.

**210. Experimental Psychology (4)** NS fall-spring
Data collection and research methods in various areas of psychology with humans and other animals. Laboratory exercises, report writing and an independent research project. Prerequisites: Psyc 110 and consent of department chairperson. Richter

**305. Abnormal Psychology (3)** SS fall
The patterns, causes, and treatment of various forms of abnormal behavior. Supplemented by sessions at Allentown State Hospital. Prerequisite: Psyc 1 or 11, and three additional hours of psychology or consent of the department chairperson. Williams

**307. Seminar in Cognition (3)** NS fall
Topic varies from year to year. In-depth examination of selected topics in cognitive psychology, e.g., concept learning, decision making, social cognition. Prerequisite: Psyc 117 or consent of instructor. Malt

**320. (CSc 310, Educ 320) Psycholinguistics (3)** spring
Study of the experimental and observational literature on psychological processes involved in the production, comprehension, and use of language by adults. Rubenstein, Malt

**331. Humanistic Psychology (3)** SS spring
The literature of and metaphors underlying the humanistic point of view in psychology. These "models of man" are contrasted with models underlying other modes of psychological inquiry. Prerequisite: Psyc 1 or 11. Newman

**335. (Biol 335) Animal Behavior (3)**
Discussion of the behavior of invertebrates and vertebrates and analysis of the physiological mechanisms responsible for behavioral actions. Emphasis on perception, environmental stimuli, and adaptive value of special behavior patterns. Prerequisite: Biol 21 or consent of the department chairperson. Itzkowitz

**337. (Biol 337) Sociobiology (3)**
Social systems of vertebrate and invertebrate groups. Emphasis on ecological and evolutionary factors that influence social behavior. Prerequisite: Biol 21 or consent of department chairperson. Not open to students who have taken Biol 498. Itzkowitz

**343. (SR 343) Scientific Methods for Applied Social Sciences (3)**
Problems in the application of scientific methods in policy relevant research. Prerequisite: introductory statistics or consent of the department chairperson. Campbell

**345. (SR 345) Seminar on the Social Evolution of Complex Organizations (3)**
Topic varies from year to year. May be taken more than once. Possible topics: Evolution of archaic city states. Role of theism and theocracy. Moral norms as socially evolved curbs to the dysfunctional species-personality produced by biological evolution. Parallel problems in modern bureaucracy. Campbell

**347. (SR 347) Seminar on Sociology and Psychology of Science (3)**
Specific topic varies from year to year. May be taken more than once. General focus is on those sociological and psychological processes in science that are relevant to the credibility of a science's claim to be improving its validity. Campbell

**351. Cognitive Development in Childhood (3)** SS spring
Piaget and alternative theoretical approaches. Research on development of memory, comprehension, communication, classification, and social cognition. Prerequisite: Psyc 107, 117, or CogS 101.

**352. (SpEd 331) Emotional and Behavioral Disorders (3)** SS
Definition, classification, etiology, treatment, and historical perspective of individuals with emotional and behavioral disorders.

**353. Personality Theory (3)** SS fall
Review and critique of theories of personality and their associated systems of psychotherapy. Includes developing knowledge and theory about people as well as the theoretical concepts themselves. Prerequisite: Psyc 1 or 11. Hyland, Williams

**354. Personality Assessment (3)** SS spring
Methods of describing and measuring personality. Observational techniques, interviews, self-report inventories, intelligence tests, and projective tests. Prerequisite: Psyc 1 or 11, and consent of the department chairperson. Hyland, Williams

**361. Special Topics in Adult Development (3)** SS
Topic varies from year to year. Personality and social development during the adult years, including sex roles, attitudes toward and stereotypes of the elderly, psychology of death and dying. Prerequisite: Psyc 109 or consent of instructor. Hyland

**363. Social and Personality Development (3)** SS fall
Social cognitive, family systems, and psychoanalytic approaches. Research on development of parent and peer relations, sense of self, and social competence from birth to adulthood. Prerequisite: Psyc 107, 108, 109 or consent of instructor. Pipp

**371. Theories of Learning (3)** NS spring
Critical evaluation of classical and contemporary theories of learning including review of relevant experimental research. Prerequisite: Psyc 171. Brody, Richter

**373. Sensation and Perception (3)** NS spring
Receptor processes of vision, audition, touch, taste, and smell. Psychological dimensions of such processes leading to consideration of perception as characteristic of organisms. Prerequisite: Psyc 65 or 176 or 177. Shortess

**374. Sensation and Perception Laboratory (1)** NS spring
Laboratory exercise applying quantitative methods to the study of sensory processes. Prerequisites: Psyc 210; Psyc 373, previously or concurrently. Shortess

**375. (Biol 375) Neuroanatomy of Behavior (3)** NS spring
Neuroanatomy and neurophysiology of animal and human behavior. Feeding, thirst, sleep, emotions, learning, and psychopathology. Prerequisite: Psyc 177 or Biol 220 or 223 or 335. Simon, Nyby

**376. Physiological Psychology Laboratory (1)** NS fall
A survey of techniques in physiological psychology. Prerequisite: Psyc 375, previously or concurrently. Nyby, Shortess

**377. Seminar in Physiological Psychology (3)** NS
Selected topics examining the physiological and/or genetic determinants of human and animal behavior. Prerequisite: Psyc 177 and consent of instructor. Shortess, Nyby, Simon

**382. (Biol 376) Endocrinology of Behavior (3)** NS
Hormonal effects upon animal and human behavior. Emphasis on neuroendocrinology of steroid hormone involvement in reproductive behaviors. Prerequisite: Psyc 177 or Biol 220 or 223 or 335. Nyby, Simon

**385. Programming Applications to Psychological Instrumentation (3)** NS spring
The computer in the psychological laboratory: PASCAL on the Apple computer: real-time acquisition of data; computer control of

experiments. Prerequisites: CSc 11 or CSc 17 and Psyc 210 or consent of instructor. Kay

**395. Thesis (3)** fall
Written report: Literature review and design of project in selected area of psychology. Intended for senior majors in psychology only. Prerequisite: consent of the chairperson.

**396. Thesis (3)** spring
Execution of project designed in Psych 395. Final report and oral presentation. Prerequisite: Psyc 395 and consent of the department chairperson.

## For Graduate Students

The department of psychology offers the doctor of philosophy degree in general experimental psychology (e.g., learning, physiological, cognitive, developmental, personality, perception). The program emphasizes research and teaching. Students are trained for university teaching or other positions involving basic or applied research.

**Requirements for a doctoral degree at Lehigh.** The Graduate School requires ninety credit hours for a doctoral degree for those entering with a bachelor of arts or bachelor of science degree; sixty credit hours are required for those entering with the master of arts or master of science. All doctoral candidates are required to spend at least one year in residence, i.e., in full-time work toward the degree.

**Requirements for a doctoral degree in the Department of Psychology:**

**Research**
All graduate students are expected to be involved in research throughout their graduate careers. There are also several formal research requirements of the program.

**First Year Project.** First year students are expected to choose an adviser and begin to work on a research project as early as possible. A written and oral report of the student's research activities must be made to the department at the end of the first year.

**Master's thesis.** An empirical (data-based) master's thesis is required. An oral presentation of the thesis is made to the department. Students entering with a master's degree may submit their thesis in fulfillment of the departmental thesis requirement with faculty approval.

**Doctoral dissertation.** This is an original piece of scholarly work. For the doctor of philosophy, this is usually empirical research, although original theoretical or historical research is possible with faculty approval.

**Coursework**

**Proseminar.** All students must complete a three-semester proseminar which provides general background in the major areas of psychology. During each semester several faculty members will teach in their areas of specialization.

**Psyc 421 and 422, Analysis and Design of Experiments.** These courses represent a two-semester sequence of theoretical and applied statistics and research methodology.

**Psyc 400+, Graduate Seminars.** After completing the proseminar sequence, students must take at least four graduate seminars approved by the faculty. Two of these seminars should be in the student's area of interest and two seminars should be from another area.

**Psyc 409, Teaching Seminar.** A one-credit discussion group often integrated with current graduate student teaching experiences; required for four semesters.

**Teaching**
Students are encouraged to participate in teaching as appropriate for their training throughout their graduate years. Normally, students begin as teaching assistants and progress to teaching independently.

**Psyc 465, Teaching Internship,** involves teaching a course with faculty supervision and follows completion of the master's degree (including an approved thesis).

**General Examination**
This is required for all doctoral candidates and must be passed at least seven months prior to the awarding of the degree. The student may opt for a major/minor or a major only exam; subareas to be covered on the exam are selected by the student in consultation with the student's general exam committee. An oral examination follows faculty evaluation of the written exam.

**Evaluation**
Graduate students are evaluated on their performance in course work, research, teaching, assistantship assignments, and the general examination. Following the end of each academic year, the faculty provides each student with a written evaluation of progress in the graduate program.

**Financial Support**
Support is available in the form of teaching and research assistantships, fellowships, and scholarships. There are special fellowships for minority students. While a good undergraduate background in psychology is desirable, promising students with majors other than psychology ar encouraged to apply.

**How to apply**
Applications for admission and financial aid maybe obtained from the Department of Psychology. Completed application forms plus transcripts, letters of recommendation, and a report of scores on the Graduate Record Examination and advanced tests in psychology should be returned to the office of admission not later than February 1 of the year of admission. New students are normally accepted for entrance into the program only for the fall semester.

## Graduate-Level Courses

**402. (SchP 402, SpEd 402) Behavior Modification (3)**
Theory and applications of behavior modification methods in classroom and clinical settings. Methods derived from operant, classical, and cognitive models. Topics include behavior analysis, charting behaviors, outcome research, and ethical and philosophical issues. Prerequisite: HD 400 or its equivalent.

**403. Proseminar: Learning and Cognition (3)**
Theoretical and empirical issues addressed by faculty members specializing in these areas. Prerequisite: graduate standing in psychology or consent of department chairperson. Brody, Malt, Richter, Williams

**404. Proseminar: Biopsychology and Perception (3)** spring
Theoretical and empirical issues addressed by faculty members specializing in these areas. Prerequisite: graduate standing in psychology or consent of department chairperson. Nyby, Shortess, Simon

**405. Proseminar: Development and Personality (3)** spring
Theoretical and empirical issues addressed by faculty members specializing in these areas. Prerequisite: graduate standing in psychology or consent of department chairperson. Barrett, Hyland, Pipp, Williams

**409. Professional Seminar (1)** fall-spring
Two hours of class meetings per week of first- and second-year graduate students to discuss teaching psychology and preparing for the profession. May be repeated for credit. Shortess

**421. Analysis and Design of Experiments (3)** fall
First of a two-semester sequence covering a variety of issues in theoretical and applied statistics with emphasis on inferential statistics and analysis of variance. Richter

**422. Analysis and Design of Experiments (3)** spring
Continuation of Psyc 421. Prerequisite: Psyc 421. Richter

**434. Seminar in Personality Theory (3)**
Selected topics in personality theory and research, including personality change, the self, personality consistency, and the relationships among thought, emotion, and behavior. Prerequisite: Psych 405. Williams

**435. Abnormal Psychology (3)** fall
The patterns, causes, and treatment of various forms of abnormal behavior. (Intended for graduate students in the College of Education.) Williams

**441. Communicating Psychological Concepts (3)**
How to organize facts and ideas into broader meaningful units that are readily communicable. Includes media aids. Prerequisite: consent of the department chairperson. Newman

**448. Seminar in Psycholinguistics (3)**
Selected topics in psycholinguistics examined in depth and in detail. Prerequisite: CSc 310. Rubenstein

**450. Special Topics in Mathematical Models and Statistics (3)**
Selected topics in the application of mathematics to psychological research. May be repeated for credit. Brody, Richter

**451. (Educ 451) Theories of Learning (3)** fall
In-depth study of major classical and contemporary learning theories. Review of experimental research relevant to theories. (Intended for graduate students in the College of Education.) Brody

**453. Advanced Topics in Learning (3)**
An intensive study with emphasis on current research of discrimination learning, avoidance learning, concept learning, problem solving, or verbal learning. May be repeated for credit. Prerequisite: Psyc 403 or consent of instructor. Brody, Richter

**460. Special Study (1-3)** fall-spring
Study of some special topic not covered in the regular course offerings. May be repeated for credit.

**461. Research Seminar (1-3)** fall-spring
Original research projects not connected with master's or doctoral theses are designed and executed in collaboration with the faculty. Students meet with the seminar director to critique each other's projects.

**465. Teaching Internship (3-6)** fall-spring
The preparation, teaching and grading of one or two undergraduate courses with appropriate supervision by members of the faculty. Observation and evaluation of the intern via classroom visits and videotapes. May be repeated for credit.

**471. Applied Psychology Internship (1-6)** fall-spring
Supervised, independent field work experience in e.g., industry, a medical setting, or a mental health setting. May be repeated for up to six hours credit.

**472. Special Topics in Physiological Psychology (3)**
Examination of the biological substrates of behavior. Topics may include animal communication, sociobiology, behavioral endocrinology, or behavior genetics. May be repeated for credit. Prerequisite: Psyc 404 or consent of instructor. Nyby, Simon

**473. (Coun 457) Personality and Adjustment (3)**
Theories of personality and adjustment with emphasis on the adjustment processes in an educational setting. Prerequisite: consent of the program director. Hyland, Williams

**474. (Educ 474) Psychological Development in Childhood (3)** spring
Survey of theories and research concerning perceptual, cognitive, social, and personality development through infancy and childhood. (Intended for graduate students in the College of Education.) Hyland, Pipp

**475. (Coun 460) Theories of Psychological Counseling (3)**
Analysis and synthesis of concepts drawn from counseling theorists. Research and current trends in counseling concerning educational, social and vocational problems. Prerequisite: admission to program in counseling.

**476. Seminar in Cognition (3)**
Selected topics in human information processing, including such areas as attention, memory, language and comprehension, and decision-making. Area of emphasis will vary from year to year. Prerequisite: Psyc 403 or consent of instructor. Malt

**480. Seminar in Cognitive Development (3)**
Selected topics in cognitive development in infancy and childhood, including such areas as conceptual development, memory development, the development of reasoning abilities, and language acquisition. Emphasis will vary from year to year. Prerequisite: Psyc 405 or consent of instructor. Barrett

**481. Seminar in Social Development and Personality (3)**
Social cognition, family systems, and psychoanalytic approaches to social and personality development from birth through adulthood. Prerequisite: Psyc 405 or consent of instructor. Pipp

**482. Seminar in Adult Development (3)**
Application of lifespan developmental theory and methodology to personality, social, and cognitive development in adulthood. Prerequisite: Psyc 405 or consent of instructor. Hyland

**486. Seminar in Clinical Psychopharmacology (3)**
Examination of diagnostic issues and pharmacological intervention strategies in the treatment of neuroses, psychoses, and other psychological/psychiatric problems. Emphasis on consideration of current primary references with evaluation through student presentations. Prerequisite: Psyc 404 or consent of instructor. Simon

**487. Seminar in Visual Perception (3)**
Examination of selected topics of current interest in visual perception from behavioral, cognitive, and neurophysiological approaches. Prerequisite: Psyc 404 or consent of instructor. Shortess

# Public Relations

See listings under Journalism.

# Religion Studies

**Professors.** Norman J. Girardot, Ph.D. (Chicago), *chairman;* Hubert L. Flesher, M.A. (Yale).
**Associate professors.** Laurence J. Silberstein, Ph.D. (Brandeis), *Philip and Muriel Berman Professor of Jewish Studies, and director, Lehigh Valley Center for Jewish Studies;* Lenore Weissler, Ph.D. (Pennsylvania).
**Assistant professor.** Michael Raposa, Ph.D. (Pennsylvania).
**Instructor.** Linda Strohmier, M.A. (Princeton), A.B.D. (Princeton).

Religion studies is committed to the academic investigation of religion as an intrinsic and vital dimension of human culture. The scholarly study of religion is an integral facet of liberal education. The student of religion is engaged in the critical and interpretive task of understanding patterns of religious thought and behavior as aspects of the human cultural experience.

Religion studies is interdisciplinary in that it draws upon humanistic (involving historical and philosophical perspectives), social scientific (involving sociological, anthropological, and psychological perspectives) modes of inquiry. Religion studies is a cross-cultural, comparative discipline concerned with the character and significance of the major religious traditions of the world. The student of religion confronts ethical problems and foundational issues of value and meaning raised by modern pluralistic and technological society.

## *Program of Study*

Courses in the department of religion studies reflect the interdisciplinary and cross-cultural nature of the field. The various offerings in the department focus on three interrelated areas.

Historical courses stress the nature and development of particular religious traditions from both the East and the West—e.g. Judaism and Hebrew Scriptures; New Testament; Christianity I and II; The Islamic Tradition; Religions of Japan; Religions of China; Religion and the American Experience; and Religions of India.

Comparative and thematic courses concentrate on special historical or methodological topics related to the general cultural significance of religion—e.g. The Jewish-Christian Encounter, Sex and Gender in Religious Traditions, Islam in the Modern World, Topics in Asian Religions.

Analytical courses are concerned with the significance and meaning of religion in the contemporary secular and technological world (involving philosophical, ethical, theological, sociopolitical, and aesthetic questions)—e.g. Science, Technology and the Religious Imagination; Religion and the Arts; Contemporary Theology; Myth and Meaning in Religion; Religion, Ethics, and Society; Topics in the Philosophy of Religion.

## *Opportunities in the Study of Religion*

Students are encouraged to enroll in any course offered by the department, either as general electives or in a major/minor program. The interdisciplinary character of religion studies makes the pursuit of a major/minor concentration in relation with other fields especially appropriate. Religion studies may be combined with other fields as part of a joint major, double major, or minor program.

A major or minor program linked to other humanistic or social scientific fields is therefore both recommended and invited. Lehigh students have, for example, combined a religion studies major not only with traditional humanistic disciplines but also with such diverse fields as mechanical engineering, electrical engineering, economics, biology, mathematical physics, social relations, international relations, and psychology. Special programs of study can be tailored to the specific needs and interests of the student.

Since religion studies addresses fundamental questions of personal value and social concern, students have found a concentration in the study of religion a stimulating complement to pre-professional programs in law, medicine, business, foreign careers, and journalism. The study of religion is especially applicable to vocations in teaching, ministry, counseling, social work, journalism, and publishing.

Some background and training in religion studies is most of all an excellent preparation for careers where a broad liberal education, cross-cultural awareness, critical modes of thought, and a concern for human values are important.

## *Major in Religion Studies*

Students are particularly encouraged to consider a joint or double major with another major field from any of the three colleges at the university. RS 10 and 11 are the foundational courses required of all majors (exempted only with permission of major advisor and chairperson). One course from each of the following three areas is required (with permission of the advisor, some courses may qualify for more than one area).

Area 1 (historical courses stressing the nature and development of particular religious and scriptural traditions from both East and West): RS 73, 103, 105, 107, 108, 111, 114, 115, 116, 117, 119, 157, 355.

Area 2 (comparative and thematic courses concentrating on special topics related to the general cultural significance of religion): RS 53, 61, 71, 109, 121, 127, 137, 141, 151, 153, 154, 165, 171, 221, 241, 251.

Area 3 (analytical courses concerned with religion in relation to the contemporary world—involving ethical, philosophical, theological, social-political, and aesthetic questions): RS 106, 124, 133, 134, 135, 145, 163, 165, 167, 221, 224, 237, 335.

In addition to this minimum distribution, we advise a concentration in one of the three areas, *or* in one of the major religious traditions. The concentration should include at least four courses, where that is possible. Language study appropriate to the concentration is also recommended. Total of 10 courses (30 credits) for the major.

During his or her first two years, the prospective major should take RS 10 and 11, one course in their projected area of concentration and one outside of that area.

Religion studies majors are encouraged to supplement their studies through related course offerings in such interdisciplinary programs as the Jewish Studies program (see page 30), the East Asian Studies program (see page 29), and the Science, Technology, and Society program (see page 220). Those who plan to pursue graduate work are advised to study a foreign language or languages related to their area of concentration (i.e. Hebrew, Greek, and Latin for Western traditions and Chinese or Japanese for Eastern traditions). With sufficient student demand, the department can make arrangements for credit instruction in Biblical Hebrew, New Testament Greek, Classical Persian, Japanese and Classical Chinese.

**Departmental Honors**

Religion Studies majors are admitted to honors by invitation of the departmental faculty toward the end of the student's junior year. To be eligible, a student must have attained at least a 3.25 average in his or her major program by the end of the junior year. Upon admittance to honors, the student will work out a special program of studies for the senior year with the major adviser (typically involving special directed reading courses, a senior essay, etc.).

**Minor in religion studies.** The minor in religion studies consists of a total of fifteen credits. The specific courses to be taken by each student are to be decided upon jointly by the student and the departmental advisor. Ordinarily, the student will be expected to take RS 10 or 11 unless specifically exempted by the departmental chairman.

**Recommended preliminary distribution courses.** Any religion studies course may be taken to meet the Humanities distribution requirement. Freshmen may enroll in any 100-level religion studies course with the consent of the instructor. Religion studies courses such as RS 101, 107, 109, 111, 114, 115, 117, 119, 121 qualify for the Foreign Culture distribution requirement (consult updated distribution requirement lists for other religion studies courses fulfilling the Foreign Culture option).

**Recommended upperclass distribution courses.** Any course at the 100 level or above may be taken.

## Courses of Study

Freshmen must petition to take courses numbered 100 and higher; sophomores must petition to take courses numbered 200 and higher.

**10. Introduction to the Study of Religion (3)**
Basic issues and methods in religious studies. "What is religion?": the problem of definition. Role of religion in individual and group life. Staff

**11. Religions of the World (3)** fall, spring
The world's major religious traditions: Judaism, Christianity, Islam, Hinduism, Buddhism, Chinese and Japanese religions. Staff

**53. (Hist 53) Religion and the American Experience (3)**
The historic development of major American religious groups from colonial times to the present. Their place in social and political life, and the impact of the national experience upon them. Emphasis on religious freedom and pluralism, and the church-state relationship.

**61. End of the World (3)**
Expectations of future destruction and bliss in biblical and other writings. Social function of millennial religious groups.

**71. Limits of Christian Tolerance (3)**
Consideration of conflict between Christianity's teaching of love, mercy, and justice, and its institutional history of exclusivism and persecution. Topics include changing Christian attitudes toward heresy, religious enthusiasm, witchcraft, sexual non-conformity, non-Christian religions and secular science.

**73. Introduction to Judaism (3)**
Development of traditional Judaism; readings in the Bible, the Talmud, and selected mystical texts. Discussions will focus on the diverse ways in which Judaism has been understood and interpreted up until the end of the 18th century. Silberstein

**103. (Hist 103) Christianity I: Early and Medieval** (3) fall
Historical and theological investigations of Orthodox and Catholic traditions. Issues of doctrine, authority, community and liturgy.

**105. Christianity II: Reformation and Modernity** (3) spring
Origin and development of the major forms of Protestant Christianity. Interactions with Catholic traditions. Issues of faith, reason and religion, scriptural authority.

**106. Contemporary Roman Catholicism** (3)
A survey of the various intellectual, cultural, political and ecclesiastical developments that have shaped contemporary Roman Catholic life and thought. Raposa

**107. The Islamic Tradition** (3)
Origin and development of classical Islam. Topics include Muhammad and the Koran; legal, theological, and ritual institutions; the Caliphate; Islamic mysticism; Islamic cosmology and Islamic science.

**108. Modern Judaism** (3)
Fundamental themes in the experience of modern Jewry; confrontation with secular culture; crisis of religious faith; Zionism and the renewal of Jewish nationalism; the problem of Jewish identity in America; and the impact of the Holocaust.

**109. Islam in the Modern World** (3)
Islamic world during the nineteenth and twentieth centuries. Islamic responses to colonialism and modernization. Islamic movements in North Africa, Arabian Peninsula, Central Asia, Iran, India, and the Arab world.

**111. The Hebrew Bible/Old Testament** (3) fall
Theological examination of a major portion of the Hebrew scriptures, with emphasis upon literary, historical and critical problems. The near Eastern context of Hebraic religious development; the Exodus tradition and the Patriarchal Period; the conquest of the land; the development and dissolution of the monarchy; the prophetic movement. Flesher

**114. New Testament** (3) spring
Study of early Christianity, with emphasis upon early Apostolic writings. The Synoptic Gospel; the Fourth Gospel; Paul's writing; the later Epistles; the Apostolic Fathers; the development of Gnosticism; parallel Hellenistic religions; newly discovered secret gospels from the second century.

**115. Religions of China** (3)
History and meaning of the major forms of Chinese religion-especially Confucianism and Neo-Confucianism, Taoist mysticism, Buddhism (Ch'an/Zen), and popular religion. Girardot

**116. Zionism and the Renewal of Judaism** (3)
New interpretations of Judaism, the Jewish community and Jewish history developed by Zionist thinkers. Diverse currents within Jewish Nationalist thought and critical responses to Zionist ideology. Silberstein

**117. Religions of Japan** (3)
Origins and development of the major forms of Japanese religion (Shinto, Confucianism/Taoism, Buddhism, folk religion) in their cultural context; interaction with Chinese tradition; consideration of role of religion in shaping contemporary Japanese character. Girardot

**119. Religions of India** (3)
Origin, development and meaning of the major forms of Indian religious traditions. Attention to elite and popular forms of Hinduism, Yoga, early Buddhism.

**121. Gospels** (3)
Study of Matthew, Mark, Luke, John, and "other gospels" (some only recently rediscovered) from early Christianity not included in the New Testament canon. Relation of gospels to Jewish and Greco-Roman stories of healers, miracle workers, saviors, and teachers.

**124. (Phil 124) Reason and Religious Experience** (3)
A critical look, from a philosophical perspective, at some fundamental problems of religion: The nature of religious experience and belief, reason and revelation, the existence and nature of God, the problem of evil, and religious truth. Hare, Raposa

**127. Sex and Gender in Judaism: The Feminist Critique**
Writings by Jewish feminists reflecting the encounter between Judaism and feminism: prayer and ritual, women rabbis, God and God language, communal power, and marriage and divorce. Silberstein

**133. Science, Technology, and the Religious Imagination** (3)
Impact of the scientific and technological culture on the Western religious imagination. Roots of science and technology in religious ideas and images. Ways of knowing and concepts of experience in religion and science. Raposa

**134. Religion, Ethics and Society** (3)
Selected readings in philosophical and theological ethics combined with the discussion of specific moral issues. The relationship between religious and secular values. Raposa

**135. Myth and Meaning in Religion** (3)
Inquiry into the meaning of religious symbols, myths and rituals. Historical perspectives; philosophical and methodological problems. Readings in the works of Otto, Cassirer, Eliade, and Levi-Strauss. Girardot, Raposa

**137. (Anth 137) Prehistoric Religion and Technology** (3)
Origins and early development of religions, with focus on interactions of religion, magic, and technology, especially as these correlate with hunting, agriculture, and pastoral modes of subsistence. Girardot

**141. Literature of the Holocaust** (3)
Readings from the literature that records, interprets and evaluates the Nazi Holocaust of the Jews in order to consider the psychological, moral, intellectual and religious implications. Consideration of the relevancy of these implications for other genocides and massacres.

**145. Jewish Thought Since the Holocaust** (3)
Reactions to the Holocaust by major Jewish thinkers such as Wiesel, Rubenstein, Fackenheim, Buber, Heschel, Schulweis, and Berkovitz. Focus on the problem of evil and its relationship to religious faith. Silberstein

**147. Near Eastern Traditions and the Rise of Monotheism** (3)
Semitic, Indo-Iranian, Turkic religions. Polytheism's contributions to monotheisms. Hebrew religion, Christianity, Islam, Zoroastrianism, Buddhism and Hinduism. Religious texts, cultural institutions, and social developments.

**151. The Jewish-Christian Encounter** (3)
Historical analysis of relations between Jewish and Christian communities. Attention to doctrinal and liturgical similarities and differences. Special emphasis on the twentieth century.

**153. Sex & Gender in Religious Traditions** (3)
Attitudes towards men and women, sin and sexuality, and language about God in religious traditions. Celibacy, marriage, divorce, homosexuality.

**154. (Hist 154) The Holocaust: History and Meaning** (3)
The Nazi holocaust in its historical, political and religious setting. Emphasis upon moral, cultural and theological issues raised by the Holocaust.

**157. (Hist 157) The Renaissance and Reformation** (3)
The transition from medieval to modern society. Consideration of political, economic, and social forces produced by the Renaissance and their influence upon the dominant religious theme of the Reformation era. Baylor

**163. Contemporary Theology** (3)
Major twentieth century movements within Christian and Jewish

theology understood as responses to the problems of modern times. May be repeated for credit as the subject matter varies. Staff

**171. Religion and the Arts (3)**
Examination of religious themes in such areas as literature, film and painting, with shifting content from term to term. Alternate fields of study include world literature, modern prose works, the contemporary American novel, Holocaust literatures, and science fiction and fantasy. May be repeated for credit as the subject matter varies.

**213. (Clss 213) Ancient Roman Religion (3)**
Religious experience of the Roman people from prehistory to end of the Empire. Nature of polytheism and its interactions with monotheism (Christianity, Judaism). Theories of religion. Emphasis on primary source materials.

**221. Topics in Asian Religions (3)**
Selected thematic and comparative issues in different Asian religious traditions. Topics may include Buddhism and Christianity, Religion and martial arts, Asian religions in America, Taoist meditation, Zen and Japanese business, Buddhist ethics. May be repeated for credit as the subject matter varies. Girardot

**224. (Phil 224) Topics in the Philosophy of Religion (3)**
Selected problems and issues in the philosophy of religion, may be repeated for credit as the subject matter varies. Prerequisite: RS 124 or consent of the department chairperson. Raposa, Hare

**235. Islamic Mysticism (3)**
Origins and development of mysticism, cosmology and universality, philosophy and mystical teachings, allegory and metaphor in mystical literature and art; mysticism and existential meaning in modern Islam.

**237. (Phil 237) Kierkegaard and Nietzsche (3)**
Two maverick thinkers of the 19th century, concerned with religious faith, values, and the meaning of human existence.

**244. Major Figures in Modern Jewish Thought (3)**
Focus on one or two major thinkers such as Buber, Rosenzweig, Scholem, Kaplan, and Heschel. May be repeated for credit as the subject matter varies. Silberstein

**251. (Clss 251) Classical Mythology (3)**
Myth, religion and ritual in ancient Greece and Rome. Emphasis on primary sources; introduction to ancient and modern theories of myth. Cross-cultural material.

**257. Jewish Thought Since the Enlightenment (1750 to Present) (3)**
Crisis of tradition, conflicting definitions of Judaism, and the limits of interpretation as reflected in the Jewish Enlightenment (Haskalah); religious reform; Neo-Orthodoxy; Zionism and Jewish feminism. Silberstein

**265. Great Figures in Western Religion (3)**
In-depth study of the life, times, and writings of important shapers of Western religious traditions. Emphasis on careful reading of representative works of such figures as Augustine, Maimonides, Averroes, Martin Luther, Martin Buber. May be repeated for credit as the subject matter varies.

**335. (Anth 335) Religion, Symbolism and Cosmology (3)**
How human experience is mediated through the use of symbols. Religious and cosmological systems in cross-cultural perspective. Frankel, Gatewood

**355. (Hist 355) European Intellectual History (3)**
Political and religious thought and other aspects of the history of ideas in Europe from the Middle Ages to about 1700. Baylor

**361. Fieldwork (3)**
Opportunity for students to work, or observe under supervision, religious organizations or institutions. Consent of chair required.

**371. Special Topics (1-3)**
Intensive study in areas appropriate to the interests and needs of students and staff.

# Russian and Russian Area Studies

See listings under Modern Foreign Languages and International Careers.

# School Psychology

See listings under Education.

# Science and Technical Writing

See listings under Journalism.

# Science, Technology and Society

Stephen H. Cutcliffe, Ph.D. (Lehigh), *program director.*
Steven Louis Goldman, Ph.D. (Boston), *Andrew W. Mellon Professor in the Humanities.*

The Science, Technology and Society (STS) Program is the product of a continuing intercollege effort to create a common ground from which to explore the relations between science, technology and society: between ideas, machines and values.

The STS Program serves as a focal point for a wide range of courses that study the natures of science and of technology, and analyze their social and personal implications. It lends coherence and visibility to offerings otherwise dispersed throughout the catalog.

## STS Studies Major

The major in Science, Technology and Society Studies prepares students for graduate study or for a wide variety of career opportunities including policy analysis, planning, or community relations with public or private sector agencies concerned with the social relations of scientific research and technological innovation. The intrinsically cross-disciplinary character of science-technology-society interactions is reflected in the B.A. requirements. Majors must complete a minimum of 31 credit hours in STS courses, listed below, together with at least 18 credit hours in any traditional academic discipline: engineering, physical or life science, the humanities, or the social sciences. This collateral set of courses should be chosen in consultation with the Program Director to provide the foundation needed to engage STS Studies issues in which that discipline is implicated. The senior seminar and project provide an opportunity for students to integrate the knowledge they have gained and the skills they have acquired, in the course of guided research on a topic of special interest to them.

STS Studies is a social science major in the College of Arts and Science, and majors must fulfill the College's B.A. distribution

requirements. A detailed description of the STS Studies major requirements and a suggested roster follows.

**Detailed Description of STS Major Requirements**

A. Required STS Courses (31 hours)
- STS 11: **Technology and Human Values**
- History 7: **The Machine in America**
- STS/Journalism 124: **Politics of Science**
- Philosophy 117: **Engineering Ethics**
- Economics 1: **Economics**
- Methods Course—choice from available courses: **Government 21; History 201, 395; Economics 145; Psychology 110; Social Relations 111, 377.**
- STS **Senior Seminar and Project**—two semesters, to be developed, 1988/89.
- **Two additional advanced courses** from the list of approved STS Studies courses.

B. Concentration in a complementary discipline (minimum of 18 hours to be chosen in conjunction with STS Studies advisor; *or* double major).

C. Science, Engineering and Mathematics Requirement
- Science Courses (10 hours):
  - 3 courses required (one with Lab)—two from **Physics, Chemistry,** or **Geology;** and one from the life sciences
- Engineering Course (3 hours):
  - **Engineering and Society**—STS 12
- Quantitative Skills Courses (6 hours):
  - 2 courses required—one must be in statistics (**Math 7** suggested) and one must be either a mathematics or a computer programming course.

**Suggested STS Major Roster**

| | | | |
|---|---|---|---|
| **Year 1** | | | |
| A&S 1 | (1) | English 2 | (3) |
| English 1 | (3) | Foreign Language | (3) |
| Foreign Language | (3-4) | Math/Computer Science | (3) |
| Math* | (3) | History 7 | (3) |
| Science Elective - Physics 11, 12 | (5) | Elective/Eco 1 | (3 or 4) |
| **Year 2** | | | |
| STS 11 | (3) | STS 12 | (3) |
| Collateral STS - 1 | (3) | STS 124/Journalism 124 | (3) |
| Humanities Elective | (3) | Collateral STS - 2 | (3) |
| Science Elective - Chem 21 | (4) | Science Elective - Biol 21 | (3) |
| Elective/Eco 1 | (3 or 4) | Humanities Elective | (3) |
| **Year 3** | | | |
| Collateral STS - 3 | (3) | Collateral STS - 4 | (3) |
| Methods Course | (3) | Humanities Elective | (3) |
| Humanities Elective | (3) | Performing/Studio Arts Elective | (3) |
| Philosophy 117 | (3) | STS Elective | (3) |
| Elective | (3) | Elective | (3) |
| **Year 4** | | | |
| Collateral STS - 5 | (3) | Collateral STS - 6 | (3) |
| STS 381 Senior Seminar | (3) | STS 382 Senior Project | (3) |
| Elective | (3) | STS Elective | (3) |
| Elective | (3) | Elective | (3) |
| Elective | (3) | Elective | (3) |

*Math 7-Statistics-Suggested

## STS Studies Minor

The Program also offers a minor in *Science, Technology & Society* Studies which is open to all undergraduates. Students electing the minor must take a set of six courses (engineering majors need only take five) clustered about one of three areas of concentration:
(1) science, technology and society;
(2) science, technology and human values;
(3) science, technology and culture.

Minors must take STS 11: *Technology and Human Values,* any four courses (for engineering majors, any three courses) in one of the above areas, and one course in any other area.

A list of all courses eligible for STS Studies follows, divided according to concentration. Students should consult with the Program Director when selecting courses for either the major or the minor.

## Science, Technology and Society Courses

**11. Technology and Human Values (3)** fall
Impact of technology on society in relation to ethical problems raised by the exploitation of technological innovations. Illustrations from literature, art, philosophy, history, folklore, and film. Cutcliffe

**12. Engineering and Society (3)**
An examination, from the perspective of its social context, of engineering as a distinctive problem-solving discipline. The roles of design, modeling, testing, safety analysis, product and client in defining engineering problems and acceptable solutions to them. Pense, Goldman

**113. Science and Human Values (3)** spring
Investigation of the relationship between theories of nature and theories of Man. Classical, modern, and contemporary scientific interpretations of nature examined for the interpretations of Man embedded in them. Goldman

**121. Technology, Engineering and Public Policy (3)**
The commercial nuclear power industry, civilian space programs and genetic engineering serve as vehicles for examining the interaction of political, social and personal values with technical knowledge in establishing research and innovation policies. Goldman

**124. (Jour 124) Politics of Science (3)** spring
Organization of the U.S. scientific community and how it interacts with government, the mass media and the public. Friedman

**141. Science and Technology Studies in East Asia (3)**
The development of science and technology in East Asia with emphasis on Japan and China. Cultural and religious influences, both internal and external, and interactions with the West, as illustrated by the development of bronze technology, ceramics and architecture. Factors in Western and Japanese society that have contributed to the rapid growth of Japanese technology as well as limits to future growth of technology in East Asia. Notis

**145. (Hist 145) Introduction to the History of Science (3)**
The history of modern science, primarily physical and biological, with emphasis on the development of major theoretical models since the seventeenth century. Goldman

**181. Independent Study** fall-spring
Prerequisite: consent of the program director.

**381. Senior Seminar (3)**
In-depth study of selected topics in science, technology and society. Subject matter may vary from semester to semester. Prerequisite: STS 11 or consent of program director. Goldman, Cutcliffe

**382. Senior Project (3)**
Continuation of STS 381. Students conduct and present independent research projects on STS topics of special interest. Prerequisite: STS 381. Goldman, Cutcliffe

**Other STS courses.** The following courses, appropriate to STS Studies, are offered by various departments. Course descriptions may be found under the catalog entry for the individual department. New courses are frequently added to this list and announced in bulletins published by the STS Program. For further information, please contact the program director.

### *I. Science, Technology and Society*

| | |
|---|---|
| Anth 131 | Science, Technology, and Society—Frankel |
| Anth 151 | Utopias and Alternative Communities—Frankel |
| CSc 252 | Computers and Society—Barnes |
| Eco 311 | Environmental Economics—McNamara |
| Eco 314 | Energy Economics—McNamara |
| Geol 11 | Environmental Geology—Evenson |
| Govt 111 | The Politics of Environment and Natural Resources—Wurth |
| Govt 115 | Technology as Politics—Wurth |
| IR 41 | Science, Technology & International Relations—Slouka |
| IR 80 | Politics of Oil—Staff |
| IR 85 | Alternative World Futures—Wylie |
| IR 337 | Seminar in International Politics of Technology—Slouka |
| SR 347 Psyc 347 | Seminar in Sociology and Psychology of Science—Campbell |
| Soc 135 | Medicine and Society—Lasker |
| Jour 125 | Environment, Public, and Mass Media—Friedman |
| STS 12 | Engineering and Society—Pense and Goldman |
| STS 121 | Technology, Engineering and Public Policy—Goldman |
| STS Jour 124 | Politics of Science—Friedman |

### *II. Science, Technology and Human Values*

| | |
|---|---|
| Engl 89 | Science Fiction—Arbur |
| Engl 119 | Literature and Technology—Gallagher |
| Engl 187 | Themes in Literature: Utopian Literature—Harson |
| STS 113 | Science and Human Values—Goldman |
| Mus 153 | Electronic Music—Salerni |
| Psyc 65 | Perception and The Visual Arts—Shontess |
| Phil 114 | War, Morality, Ethics, and Military Professionalism—Hare |
| Phil 115 | Business Ethics—Staff |
| Phil 116 | Medical Ethics—Dillon |
| Phil 117 | Engineering Ethics—Dillon |
| Phil 128 | Philosophy of Science—Bearn |
| Phil 228 | Topics in the Philosophy of Science—Goldman |
| Phil 250 | Minds of Men and Robots—Melchert |
| RS 133 | Science, Technology & The Religious Imagination—Raposa |
| RS 137 Anth 137 | Prehistoric Religion and Technology—Girardot |
| Thtr 161 | Theater Design and Engineering—Milet |

### *III. Science, Technology and Culture*

| | |
|---|---|
| Arch 207 | Renaissance Architecture—Adams |
| Arch 209 | Architecture, 1750-1880—Adams |
| Arch 210 | 20th-Century Architecture—Zaknic |
| Clss 108 | Ancient Technology—Staff |
| Clss 204 Arch 204 | Ancient City and Society—Staff |
| Hist 7 | Machine in America—Smith |
| Hist 8 | History of Medicine in America—Ellis |
| Hist 31 | History of Japanese Industrialization Since 1800—Cooper |
| Hist 111 | Engineering in the Modern World—Smith |
| Hist 301 | Seminar in the History of Technology—Simon, Smith, Cooper |
| Hist 337 | History of Medical Thought—Ellis |
| Hist 339 | Topics in American Public Health—Ellis |
| Hist 340 | Topics in American Medicine—Ellis |
| STS 141 | Science and Technology Studies in East Asia—Notis |
| STS/Hist 145 | Introduction to the History of Science—Goldman |
| STS/Met 221 | Materials in the Development of Man—Notis |

# Social Psychology

See listings under Social Relations.

# Social Relations

**Professors.** Donald T. Campbell, Ph.D. (Berkeley), *University Professor of Social Relations and Psychology;* Barbara B. Frankel, Ph.D. (Princeton); Roy C. Herrenkohl, Ph.D. (N.Y.U.); Judith N. Lasker, Ph.D. (Harvard); James R. McIntosh, Ph.D. (Syracuse), *chairperson;* Robert E. Rosenwein, Ph.D. (Michigan).

**Associate professors.** John B. Gatewood, Ph.D. (Illinois).

**Visiting Assistant professors.** Karen Hicks, M.A. (Lehigh); Joan Z. Spade, Ph.D. (SUNY-Buffalo).

Social relations, broadly conceived, is the study of human beings in relationships with others. As such, it encompasses the study of the broadest range of human social activities from the comparative examination of widely divergent cultures and societies to the inner life of the individual as this influences social behavior.

The three disciplines represented in this department—anthropology, sociology and social psychology—have as their goal to foster both self-awareness and societal awareness by providing students with the knowledge and analytic skills necessary to the accomplishment of these aims. The disciplines represented in the program provide a student with a clearer understanding of self. To study social relations is to develop a sense of the influences that have shaped one's past and pattern one's future.

But self-awareness is only a beginning. Human behavior occurs within diverse settings, groups and other collectivities. Coping with and resolving conflict, reducing strain and tension, and managing and building cooperation are central themes of study in departmental courses. Whether in the study of primitive kinship systems, the messages of nonverbal behavior, or the elements of wealth and power, one comes closer to an understanding of social life in organizations, organizational behavior and the structure of groups and societies.

### *Research Opportunities*

It is the explicit aim of the social relations department to involve majors, minors and other interested students in the ongoing research activities of faculty members. A list of current research programs and research assistant opportunities is maintained in the departmental office in Price Hall.

Second-semester sophomore, junior and senior students interested in a supervised research experience are invited and encouraged to consult the list and talk with the appropriate faculty member. Course credit may be received for research experience.

### *Fieldwork in Social Relations*

The department maintains close, working relationships with a variety of social agencies and institutions in the area. Students may earn course credit by carrying out supervised work in field settings, e.g., hospitals, private and public agencies devoted to social services, courtrooms, prisons, etc. This useful experience allows a student to apply the concepts learned in the classroom to a field setting and to evaluate vocational aspirations and interests.

Students interested in social work may take courses in the Social Work Education Program, an undertaking of the Lehigh Valley

Association of Independent Colleges. For further information, contact the social relations department.

## *Social Relations and Careers*

Social relations majors are found in business, industry, government, the service areas, and the academic world. Some Lehigh students have gone on to earn the master's degree or the doctor of philosophy. Many have sought professional degrees. For example, training in the social sciences is excellent preparation for law school or seminary programs. Most students go from the university directly to work. Graduates are planners, administrators, case-workers, interviewers, personnel officers, health and welfare workers, sales representatives, consultants, researchers, media managers, owners of their own business, as well as career military people.

A major in social relations provides a strong core around which students can develop career-based programs of study.

For example, a person interested in public health would add courses in biology, management and psychology to the requirements for the social relations major. Someone interested in personnel work might take courses in psychology, management, and marketing. A prospective law student might elect the Law and Legal Institutions minor in addition to the social relations major. A student who is interested in a career in the social services or the helping professions might elect a double major in social relations and psychology or an interdisciplinary major in those two fields.

Of particular interest to those students in a career in business administration is the bachelor of arts-master of business administration degree (Arts B.A.-M.B.A.). In this option, a student would major in social relations, take requisite courses in the College of Business and Economics, and then take additional study in business administration beyond the bachelor of arts degree. This program is described in more detail in the College of Arts and Science entry, Section III.

A list of updated university courses specific to these options is on file in the departmental office. There are, of course, many other career possibilities. Students interested in formulating a particular career-based program of study should consult the department chairperson, who serves as department career adviser.

## *Major Requirements in Social Relations*

A major in social relations consists of 36 hours of course work. This total includes 15 credits of core courses (6 in introductory level courses and 9 in theory and methodology) and 21 hours of electives. Students are required to have a minimum of 6 hours from each discipline. A student may concentrate in any one discipline by taking 12 elective credits in anthropology, social psychology, or sociology.

### *Core Courses* (15)

**Introductory** (6)

| | |
|---|---|
| Anth 11 | Sociocultural Anthropology (3) |
| Anth 12 | Emergence of Mankind and Culture (3) |
| SPsy 21 | Social Psychology (3) |
| Soc 5 | Introductory Sociology (3) |

**Theory and Methodology** (9)

| | |
|---|---|
| SR 111 | Research Methods of Social Relations (3) |
| SR 377 | Computer Applications in Social Relations (4) |
| SR 381 | Development of Social Theory (3) |

**Elective** (21 hours)

## Requirements for the Minor

**Social relations:** One introductory course, SR 111 and nine additional credits at the 100 level or above, three hours from each discipline.
**Anthropology:** Anth 11 or 12, SR 111 and nine additional credits at the 100 level or above in anthropology.
**Social Psychology:** Soc Psych 21, SR 111 and nine additional credits at the 100 level or above in social psychology.
**Sociology:** Soc 5, SR 111 and nine additional credits at the 100 level or above in sociology.
**Interpersonal Behavior in Small Groups and Organizations:** See description under Special Academic Opportunities.

## Honors Option

A student may be graduated with honors by completing an independent project supervised by one or more members of the faculty. Students who elect this option will be required to take a readings course (SR 371 or 372) and SR 399 (senior project).

Students who intend to go on to graduate school should particularly consider electing the honors option. The department chairperson should be consulted for further details.

## Undergraduate Courses in Social Relations

**SR 41. Human Sexuality (3)**
Sexuality and gender roles across the life cycle, including human reproduction, decision-making, and the societal regulation of sexual behavior. Stinson

**SR 111. Research Methods of Social Relations (3) fall**
Theory and methodology of research in social relations. Use of contemporary journals and other materials as an introduction to research skills in anthropology, sociology and social psychology.

**SR 112. Research Methods in Social Relations (3) spring**
Continuation of SR 111. Developing skills in conducting social research. Prerequisite: SR 111.

**SR 118. Close Personal Relationships (3)**
Dynamics of development, maintenance and dissolution of relationships with family, close friends, lovers and spouses. Life cycle of relationships, attraction, communication.

**SR 171. Seminar in Social Relations (3)**
Topics in social relations, anthropology, sociology, and social psychology. Topics vary. May be repeated for credit.

**SR 331. Social Perspectives on Death and Dying (3)**
The meaning of the end of life in various societies, especially the United States. Sociological, anthropological, and psychological perspectives on dying as a process, and on death as an event, combined with philosophical and ethical considerations. Topics to be considered include euthanasia and "extraordinary means" to maintain life from neonate to elderly, funeral practices, stages of dying, hospices, and the social milieu and family relationships of the dying person. Blank

**SR 343. Scientific Method for Applied Social Sciences (3)**
Problems in the application of scientific methods in policy relevant research. Prerequisite: introductory statistics or consent of the department chairperson. Campbell

**SR 345. (Psyc 345) Seminar on the Social Evolution of Complex Organizations (3)**
Topic varies from year to year. May be taken more than once. Possible topics: Evolution of archaic city states. Role of theism and theocracy. Moral norms as socially evolved curbs to the dysfunctional species-personality produced by biological evolution. Parallel problems in modern bureaucracy. Campbell

**SR 347. (Psyc 347) Seminar on Sociology and Psychology of Science (3)**
Specific topic varies from year to year. May be taken more than once. General focus is on those sociological and psychological processes in science that are relevant to the credibility of a science's claim to be proving its validity. Campbell

**SR 363. Seminar in Social Relations (1-4)**
Selected social science topics.

**SR 365. Fieldwork in Social Relations (1-3)**
Supervised work experience and observation in a variety of field settings, e.g., hospitals, social services, public agencies, private

organizations. Prerequisite: consent of chairperson. Lasker, Rosenwein

**SR 371. Special Topics in Social Relations (1-3)**
An opportunity for advanced work through supervised reading and research. Prerequisite: consent of the department chairperson.

**SR 372. Special Topics in Social Relations (1-3)**
Continuation of SR 371.

**SR 377. Computer Applications in Social Relations (4)**
Uses of micro- and mainframe computers in the social sciences, including data management, statistical analysis, and simulations. Weekly laboratory sessions.

**SR 381. Development of Social Theory (3)**
Comparative study of social theory.

**SR 393, 394. Independent Research (3-4)**

**SR 395. Methods in Observation (3)** alternate years
Naturalistic and participant observation in uncontrolled field settings. Frankel or Rosenwein

**SR 399. Senior Project (3)**
Independent work fulfilling honor requirements. Prerequisite: SR 111 or 112, or consent of the department chairperson.

## Anthropology

**Anth 11. Sociocultural Anthropology (3)**
Human behavior in cross-cultural perspective. Variations in kinship reckoning, political organization, economic and religious life in comparative perspective. Particular non-Western peoples: films and readings.

**Anth 12. Emergence of Mankind and Culture (3) NS**
Introductory biological anthropology and prehistory. Adaptive function of human culture and its relation to biological evolution. Hominid fossil record, nonhuman primate social behavior, cultural beginnings, and survey of world prehistory. Gatewood

**Anth 128. Urban Ethnology (3)**
Cross-cultural study of the city as a social milieu. Comparison of methods and strategies for research in urban settings, and the explicit and implicit theories of urban life associated with these. Field projects will use Bethlehem's South Side as an ethnographic laboratory. Frankel

**Anth 131. Science, Technology and Society (3)**
Relationships of science and technology to social life across time and space, with alternative theoretical models for understanding these relationships. Frankel

**Anth 137. (Rel 137) Prehistoric Religion and Technology (3)**
Origins and early development of religions, with focus on interactions of religion, magic, and technology, especially as these correlate with hunting, agriculture, and pastoral modes of subsistence. Girardot

**Anth 151. Utopias and Alternative Communities (3)**
Present and past searches for new forms of community in fact and fiction. Frankel

**Anth 182. North American Indians (3)**
Culture areas of native North America prior to substantial disruption by European influences north of Mexico. Environmental factors and cultural forms. Gatewood

**Anth 184. Cultures of the Pacific (3)**
Cultures of the Pacific Islands: language families, prehistories, and social organizations. Focus: Melanesian cultures. Gatewood

**Anth 305. Maritime Anthropology (3)**
Comparative study of fishing peoples and their technologies. Fishing strategies, control of information, and social organization of marine exploitation in subsistence and modern industrial contexts. Theory of common-property resources and the role of social science in commercial fisheries management.

**Anth 321. Anthropology of Physical and Mental Health (3)**
Definition and treatment of physical and mental health in cross-cultural perspective. Strategies for coping with illness in literate and nonliterate, Western and non-Western societies. Frankel

**Anth 335. (Rel 335) Religion, Symbolism and Cosmology (3)**
How human experience is mediated through the use of symbols. Religious and cosmological systems in cross-cultural perspective. Frankel

**Anth 339. Seminar in Anthropology (3)**
Topics in anthropology. Varying semester to semester: human evolution, politics and law, introduction to linguistics, human use of space, anthropology of deviance. May be repeated for credit. Frankel, Gatewood

**Anth 363. Kinship, Marriage and Descent (3)**
Kinship as the central institution in primitive social organization. Variations in definition and regulation of marriage and descent in cross-cultural perspectives. Critiques of Murdock, Levi-Strauss, and Fortes. Soc 364 recommended in conjunction with this course. Gatewood

**Anth 376. Mind, Self and Culture (3)**
Concepts and methods of studying relations between the individual and the sociocultural milieu. National character, basic and model personality structures, cross-cultural studies of cognition, ethoscience, and ethnosemantics. SPsy 135 and 307 recommended in conjunction with this course. Gatewood

## Social Psychology

**SPsy 21. (PSYC 21) Social Psychology (3)**
Theories, methods of investigation, and results of research in social psychology with emphasis on psychological processes in social behavior, social attitudes, group behavior and social interaction.

**SPsy 109. (PSYC 109) Adulthood and Aging: Social and Psychological Perspectives (3)**
Psychological, sociological and other social science approaches to the latter two-thirds of the life span. Age stratification and distribution patterns, attitudes to aging, social behavior of older adults, widowhood, issues of retirement and use of leisure time. Blank, Hyland

**SPsy 121. Social Psychology of Small Groups (3)**
Study of interpersonal behavior in groups. Survey of relevant theories and empirical research. Rosenwein

**SPsy 135. (Journ 135) Human Communication (3)**
Processes and functions of human communication in relationships and groups. Rosenwein

**SPsy 307. Attitudes, Attributions, and Actions (3)**
Social perception and cognition as studied in current social psychology. Persuasion, conformity, prejudice, stereotypes, and other social processes in relation to attitude formation and change. Anth 376 and SPsy 135 recommended in conjunction with this course. Blank

**SPsy 308. Seminar in Social Psychology (3)**
Intensive consideration of selected topics in current theory and research in social psychology. The subject matter varies from semester to semester, and includes such topics as the social psychology of education, the applications of perception and learning theory to social psychological problems, the social psychology of science, and the social environment of communication. May be repeated for credit.

**SPsy 312. Interpersonal Behavior in Small Groups (3)**
Intensive consideration of theoretical and methodological issues in the analysis of the development of small groups. Rosenwein

**SPsy 317. Contemporary Social Psychology (3)**
Study of and practice in writing, planning and editorial functions of *Contemporary Social Psychology,* a national and international publication. Rosenwein and Blank, editors of CSP

**SPsy 321. Social Psychology of Developing Adults (3)**
Approaches to social and personality aspects of adulthood and aging. Application of a lifespan developmental model and methodology to selected specific issues and current social psychological topics. Prerequisite: one social psychology or psychology course, or consent of the department chairperson. Blank

**SPsy 323. The Child in Family and Society (3)**
Influences such as marital discord, family violence, poverty and prejudice on the development of the child from birth through adolescence.

**SPsy 333. (Govt 333) Social Psychology of Politics (3)**
Political behavior viewed from a psychological and social psychological perspective. Rosenwein

**SPsy 391. Evaluation Research (3)**
Application of social research methods of evaluation of the effectiveness of social programs. Measurement, research design, criteria of effectiveness and decision making. Prerequisite: SR 111 or 112 or consent of department chairperson. Herrenkohl

**SPsy 392. Social Psychology Research Seminar (3)**
Advanced seminar in social psychological research methods: evaluation research and experimental social psychology. Recommended preparation: SR 111 or 112, or Psych 113 and 114, or consent of the department chairperson. May be repeated once for credit.

## Sociology

**Soc 5. Introductory Sociology (3)**
Social organization, stability and conflict, structure and function, and processes of social change in society.

**Soc 65. Contemporary Social Problems (3)**
Studies of major problems facing contemporary society. McIntosh

**Soc 123. Sociology of Social Welfare (3)**
Development of social welfare and human service systems in different societies, especially the United States. Issues in contemporary social welfare policy; specific service institutions (e.g., child welfare and mental health); and the role of social work and other helping professions. Lasker

**Soc 135. Medicine and Society (3)**
Health, illness, and the health profession from the sociological perspective. Social epidemiology, social psychology of illness, socialization of health professionals, organization of health care, patient-professional relationships and ethical issues in medical care.

**Soc 141. Social Deviance (3)**
Analysis of deviant social systems, supporting factors maintaining them, and societal responses to deviant roles and collectivities. McIntosh

**Soc 152. Alcohol, Science and Society (3)**
Alcohol use and abuse, its historical function in society, moral entrepreneurship, status struggles and conflict over alcohol. Current problems with attention to special population groups and strategies for prevention of alcohol abuse. McIntosh

**Soc 325. (Hist 325) American Social History, 1607-1877 (3)** fall
Social change from early agrarian communities to beginnings of industrialism, emphasizing socio-economic class, family structure, and treatment of women and minority groups.

**Soc 326. (Hist 326) American Social History Since 1877 (3)** Spring
Changing role of women, minority groups, and the family during the industrial era. Development of the modern class structure and the impact of the welfare state.

**Soc 327. Health Policy Analysis (3)**
Key issues in health policy: cost containment, quality control, preventive health practices, and distribution of health responses. Roles of government, industry, health professionals, and consumers in policy determination. Lasker

**Soc 333. Sociology of Aging (3)**
Residential patterns, social policies and services for the aged. Alternative political strategies, health programs, living arrangements and workplace choices considered. The changing roles of the elderly in American and other societies, and the special problems they face. Impact of changing age structure. Lasker

**Soc 341. Women and Health (3)**
Relationships of women to the medical system. Influence of medicine on women's lives and the impact of the women's movement on health care. Lasker

**Soc 364. Lifestyle and the Family (3)**
Historical development of families in the U.S. and issues faced by contemporary American families, including parenting, combining work and family, and divorce and remarriage. Anth 363 recommended in conjunction with this course. Spade

**Soc 370. Juvenile Delinquency (3)**
The development of delinquent behavior within its social context; an analysis of delinquent gangs and subcultures and the variable patterns of antisocial activity; and the evaluation of institutional controls and treatment of the problem. McIntosh

**Soc 373. Seminar in Sociology (3)**
Intensive consideration of selected topics in contemporary theory or research in sociology. The subject matter varies from semester to semester. May be repeated for credit.

## For Graduate Students

The department offers a master's degree program in social relations. This thirty-credit program offers both further preparation for an advanced degree and training for nonacademic careers.

Students may choose to pursue a "health and aging" specialization in our graduate program. After completing the basic theory and methods courses required of all graduate students, the student will take a set of core courses in health and aging and participate in an internship. All graduate students complete the program with a thesis.

Other options that focus on the research interests of specific faculty members are also available. In conjunction with the Center for Social Research the department offers many opportunities for research experience. For further information students should contact the department chairperson.

**SR 401. Proseminar in Applied Social Research (1-4)**
Specialized topics including advanced statistical and measurement techniques, computing methods, data base management, research design and specialized areas of research activity. Can be repeated for credit. Permission of instructor required.

**SR 411. Advanced Research Methods (3)** fall
A basic course given in research theory and methods. Consideration given the nature of theory, hypotheses testing, the definition of variables and methods of measurement. Herrenkohl

**SR 412. Practicum in Research Methods (3)** spring
Laboratory in the design and execution of research. Includes class project. Prerequisite: SR 411.

**SR 413. Fieldwork in Social Relations (3)**
Supervised work experience in a variety of field settings, e.g. hospital, public and private social service agencies and organizations.

**SR 414. Survey Research (3)**
Examination of survey methods, sample design, interview design, training of survey personnel, data management and analysis.

**SR 416. (Educ 416) Quasi-Experimentation and Program Evaluation (3)** spring

Social science research methods for non-laboratory settings. Examination of quasi-experimental research designs, threats to validity, possible controls, and uses in social program evaluation. Non-mathematical presentation. Knowledge of elementary statistics assumed. Campbell

**SR 461. Seminar in Social Relations (1-4)**

Topics in social relations: anthropology, sociology and social psychology. Topics vary.

**SR 470. Social Theory (3)** fall

Major trends in social science theory in historical context. Comparison of the major theoretical perspectives with an emphasis on underlying philosophy and the development of critical capacities in students.

**SR 471. Special Topics (1-3)**

Intensive study in an area of social relations that is appropriate to the interests and needs of staff and students.

**SR 472. Special Topics (1-3)**

Continuation of SR 471.

**SR 477. Advanced Computer Applications (4)**

Uses of computers in social sciences, including data collection, management, and analysis, simulations, and decision-making; includes weekly lab. Spade

# Sociology

See listings under Social Relations.

# Spanish

See listings under Modern Foreign Languages.

# Special Education

See listings under Education.

# Speech

See listings under Journalism.

# Technology, Interdisciplinary Courses

See listings under Science, Technology and Society.

# Theatre

**Professor.** Jeffrey Milet, M.F.A. (Yale).
**Associate professor.** Augustine Ripa, M.F.A. (Northwestern).
**Assistant professor.** Pam Pepper, M.F.A. (Ohio).
**Visiting assistant professor.** Annamaria Pileggi, M.F.A. (Brandeis).
**Adjunct Assistant professor.** Daina Robins, Ph.D. (Tufts).
**Resident designer.** Bruce Candlish, M.F.A. (Penn State).
**Business manager.** Allison Q. Blatt, B.A. (Concord).
**Costume Shop coordinator.** D. Polly Kendrick, M.A. (Arizona).

To study theatre is to examine its many internal disciplines. Acting and directing combine with design, technical theatre, dramatic literature and theatre history to form the body of our art. Students may pursue general theatre studies or focus on particular areas such as performance or design. They may major in theatre, minor in theatre or participate strictly in our production program. Students may even complete a minor in theatre from outside the College of Arts and Science.

The bachelor of arts degree in theatre is granted after at least thirty one credit hours of study. Because we believe that undergraduate theatre education should be broad based with an emphasis on diversity of experience, students are encouraged to take a variety of courses outside the major. Some students complete double majors. Those with the talents and aspirations for a career in theatre have gone to graduate schools offering intense, pre-professional training. Recent majors who have not pursued a theatrical career have gone from our program directly into careers in business, social services, sales. Theatre study is an excellent preparation for vocations in which self presentation is important, such as law. The problem solving, analytical and interpersonal skills gained from this discipline are applicable across a wide range of careers. An understanding and appreciation of the complex art of the theatre will enrich a lifetime.

In addition to its academic courses, the department sponsors an active production program in which students, faculty and guest artists collaborate. Our main performance facility is the Wilbur Drama Workshop, a large, classic black box theatre. The core of our work in this space is dedicated to productions featuring primarily student actors directed by faculty or guest artists. When possible, a highly qualified student may direct or design in the main space. In addition to our own productions, we regularly invite outside professional performers and ensembles to work with us and perform. We also operate a separate lab theatre designed specifically for student experimentation. In cooperation with the College of Engineering and Applied Science, we operate a program in theatre technology research in which selected students may participate through directed studies courses. The availability of valuable hands-on experience and the very close working relationships developed between students and faculty uniquely characterize the department of theatre.

Students interested in designing a major or minor in theatre should consult with the department chairperson. Experienced theatre students with questions regarding accurate placement in any theatre course should, likewise, consult with the chairperson.

## *Theatre Major*

Through the selection of appropriate electives, students may concentrate their major in one of these areas:

ACTING/DIRECTING
DESIGN/TECHNICAL THEATRE
GENERAL THEATRE STUDIES

The major in theatre consists of 31 hours distributed as follows:

*Coursework required of all majors, 16 hrs*

| | |
|---|---|
| Thtr 117 | Theatre History (3) |
| Thtr 123 | Dramatic Literature (3) |
| Thtr | Acting (3) any appropriate level |
| Thtr | Design (3) scenic, lighting or costume |
| Thtr 144 | Basic Directing (3) |
| Thtr 315 | Senior Study (1) |

*Electives, 15 hrs*
Not more than two theatre electives may be below 100 in number.

*Recommended electives from other departments:*
The departments of Art and Architecture, Classics, English, Modern Foreign Languages, Music and others all offer courses of value to a theatre major or minor. Consult with your advisor about scheduling these.

## *Theatre Minor*

The minor in theatre consists of 15 credit hours selected in consultation with a departmental advisor. Through the careful choice of courses students may create emphases in Acting/Directing, Design/Technical Theatre, or General Theatre Studies.

## *Departmental Honors*

The exceptional theatre student may elect to pursue departmental honors in the senior year. This student must have a gpa of 3.3 in all theatre courses presented for the major. In the fall of the senior year the student, with faculty supervision, elects a special project in a particular area of theatre. This may take the form of preparing to direct a play, researching a role to be performed, preparing a design presentation or researching in an area of theatre scholarship in preparation for the writing of a substantial report. In the spring of that year the report or project would be executed. The student would enroll in two three credit honors courses, each senior semester, graduating with a minimum of 36 hrs of theatre courses.

## *The Acting Sequence*

Students with little or no prior acting experience should elect Theatre 11, Introduction to Acting, as their first course. Students with some prior acting experience should consult with the department chairperson for accurate placement and waiver of the Theatre 11 prerequisite.

## Courses in Theatre

**Thtr 1. Introduction to Theatre (3)**
Foundations of theatre: historical, literary and practical.

**Thtr 11. Introduction to Acting (3)**
Discussion of text. Basic exercises and techniques. Preparation for scene study. Recommended for students with little or no prior experience.

**Thtr 15. Introduction to Design and Technical Theatre (3)**
Theatrical materials and methods. Basic concepts in scene design and stage lighting. Supervised practical experience.

**Thtr 61. Theatre Production (1-2)**
Supervised practical experience in theatrical production. May be repeated for credit. Prerequisite: consent of chairperson.

**Thtr 111. Theatre Sound (1)**
Techniques, materials, and methods of designing sound for theatrical production.

**Thtr 113. Stage Lighting (3)**
An introduction to the art and practice of lighting for the stage.

**Thtr 115. Scene Design (3)**
An introduction to the art of the scenic designer. History of design for the theatre. Materials, methods and techniques.

**Thtr 116. Stagecraft (3)**
Drafting, problem solving, stagecraft, rigging, materials and techniques. The role of the technical director.

**Thtr 117. Theatre History (3)**
Historical survey of western theatre from origins to present.

**Thtr 123. Dramatic Literature (3)**
Western dramatic literature. Emphasis on major authors, genres, periods.

**Thtr 144. Basic Directing (3)**
Introduction to the theatrical director's art. Scene work. Prerequisites: Thtr 1 and any acting course, or consent of chairperson.

**Thtr 147. Acting Early Modern Drama (3)**
Elements of characterization through scene study. Emphasis on work of early modern dramatists, e.g. Ibsen, Strindberg, Chekhov and others. Prerequisite: Thtr 11 or consent of chairperson.

**Thtr 148. Acting Contemporary Drama (3)**
Elements of characterization through scene study. Emphasis on works of recent dramatists, e.g. O'Neill, Williams, Miller and others. Prerequisite: Thtr 11 or consent of chairperson.

**Thtr 151. Costume Design (3)**
The history and development of theatrical costuming. Wardrobe and its relationship to art and culture.

**Thtr 161. Theatre Design and Technology (3)**
Theatre environments, equipment systems and acoustics. Functions and ethics.

**Thtr 175. Special Projects (3)**
Theatrical topics of current or special interest, e.g., mime. Can be repeated for credit as title varies.

**Thtr 181. Theatre Management (3)**
Concepts, techniques and practices related to managing the theatrical enterprise.

**Thtr 185. Production Seminar (1-3)**
Practicum in various approaches to theatre production, e.g. ensemble. Prerequisite: consent of the chairperson. Can be repeated for credit as title varies.

**Thtr 214. Advanced Lighting (3)**
Continuation of Theatre 113. Lighting design for various performance forms. Practical experience. Prerequisite: Thtr 113.

**Thtr 216. Advanced Scene Design (3)**
Continuation of Theatre 115. Advanced design problems and techniques. Practical experience. Prerequisite: Thtr 115.

**Thtr 244. Acting Styles (3)**
Acting problems in non-realistic drama, e.g. Shakespeare. Prerequisite: a 100-level acting course, or consent of chairperson.

**Thtr 245. Advanced Directing (3)**
Continuation of Theatre 144. Directorial approach. Supervised practical experience. Prerequisite: Thtr 144.

**Thtr 271. Playwriting (3)**
Techniques of the dramatist. The playwright's creative process. Practice in creating dramatic forms.

**Thtr 275. Internship (1-3)**
Professionally supervised work in theatres and theatrical organizations in the areas of performance, design, technical theatre, theatre administration and management. May be repeated for credit. Prerequisite: consent of chairperson.

**Thtr 315. Senior Study (1)**
Seminar for senior theatre majors. Enhancement of current theatre studies while preparing for further theatre studies or activity. Fall only.

**Thtr 351. Advanced Special Projects (1-6)**
Independent study in theatre. Prerequisite: consent of the chairperson. Can be repeated for credit as title varies.

**Thtr 361. Research in Theatre Technology (1-3)**
Solving technological problems in theatre. Application of new

technologies. May be repeated for credit. Prerequisite: consent of chairperson.

# Urban Studies

**Urban Studies Committee.** David Curtis Amidon, Jr., M.A. (Penn State), *lecturer in urban studies and director of urban studies;* Nicholas Adams, Ph.D. (N.Y.U.), *associate professor and chairperson of art and architecture;* Frank T. Colon, Ph.D. (Pittsburgh), *professor of government;* Barbara Frankel, Ph.D. (Princeton), *associate professor of social relations;* Warren A. Pillsbury, Ph.D. (Virginia), *associate professor of economics;* Roger D. Simon, Ph.D. (Wisconsin), *associate professor of history;* Ivan Zaknic, M.Arch. and Urban Planning (Princeton), *associate professor of architecture.*

This is an interdepartmental major program intended for students who seek a broad background in the social sciences and for those with career interests in such fields as business or law, and such specialized areas as city management, architecture and urban planning, human relations, and the helping professions.

Instruction focuses on the process of urbanization, the problems and opportunities arising therefrom, the relationship between cities and economic growth, and existing and proposed public policies relating to cities.

A minimum of 33 credit hours is required, apportioned among two levels of study. Substitutions are possible with approval of the director, who advises all those with majors and minors in urban studies. The director's office is located at 232 Chandler-Ullmann Hall.

## Undergraduate Major

**I. required preliminary courses** (9 credit hours)

| | |
|---|---|
| US 61 | The Study of Urbanization (3) |
| US 62 | Contemporary Urban Issues (3) |

one of the following two research methods courses

| | |
|---|---|
| Govt 21 | Introduction to Research Methods (3) |
| Eco 145 | Statistical Methods (3) |

**II. elective courses** (24 credit hours)

Any course may be elected from among the following:

| | |
|---|---|
| Anth 128 | Urban Ethnology (3) |
| Anth 151 | Utopias and Alternative Communities (3) |
| Arch 207 | Renaissance Architecture (3) |
| Arch 213 | The City (3) |
| Eco 312 | Urban Economics (3) |
| Eco 337 | Transportation and Spatial Economics (3) |
| Govt 77 | Urban Politics (3) |
| Govt 360 | Public Administration (3) |
| Hist 333 | American Urban History to 1880 (3) |
| Hist 334 | American Urban History, 1880 to Present (3) |
| US 363 | Philadelphia: Development of a Metropolis (3) |

Up to two courses may be elected from among the following:

| | |
|---|---|
| Arch 210 | 20th-Century Architecture (3) |
| Eco 354 | Public Finance: State and Local (3) |
| Govt 331 | Government and Law Internship (3) |
| Hist 326 | American Social History Since 1877 (3) |
| US 125 | American Ethnic Groups (3) (US 321, 324, 326 or 328 may be offered instead of US 125) |
| US 371/372 | Special Topics (3-6) |

Participants in off-campus programs, such as the Philadelphia or Washington semesters, may receive credit for up to three elective courses, depending upon the content of those courses, but they must also complete at least five courses in the first group of electives above.

**Urban studies minor.** The minor consists of US 61 and five additional courses from an approved list for a total of eighteen credit hours.

## Undergraduate Courses

**61. The Study of Urbanization (3)** fall
Introduction to the study of cities. Emphasis on sources of economic vitality, especially entrepreneurialism, and on urban sociology. Some lectures on Bethlehem and Lehigh Valley history for illustrative purposes.

**62. Contemporary Urban Issues (3)** spring
Analysis of problems, typically including planning, housing, and finance, with strong emphasis on twentieth-century New York City.

**125. American Ethnic Groups (3)** spring, 1989
Immigration to the United States; persistence of cultural differences over generations; patterns of conflict and accommodation; assimilation; ethnic politics; emphasis on white Euro-American nationality groups; with some attention to Afro-, Hispano-, Asian-, and native Americans. Amidon

**321. White Protestant Americans (3)** spring, 1990
Cultural and religious origins of the historically dominant ethnic group in the United States; rise and decline of national Anglo-Protestant urban elite; persistence of regional and nonelite subcultures; "Wasp" stereotypes and anti-Protestant themes in American culture. Amidon

**324. The Irish in American Society (3)** spring, 1991
Cultural, economic and political experience of a major white ethnic group in the United States; Irish Catholics vs. Scotch-Irish Protestants; immigrant poverty; priests and prelates, ward healers and big-city bosses; Irish themes in American literature, humor, and media culture; Irish radicalism. Amidon

**326. The American Italian Community (3)** spring, 1990
European background of Italian emigration; patterns of first-generation experience in the United States; distinctive values, folkways, and institutions; the "Mafia"; political behavior; upward mobility and assimilation; achievements of outstanding individuals; interaction with general American culture. Amidon

**328. The American Jewish Community (3)** spring, 1989
Historical and sociological perspectives on the experience of an important minority in the United States; communal institutions and social patterns; orientation toward achievement and secular success; Jewish influences in American culture; anti-Semitism, acceptance, and survival as a distinct subculture. Amidon

**363. Philadelphia: Development of a Metropolis (3)** fall
Philadelphia as an early experiment in the deliberate creation of a new community; the rise of the port; industrialization and immigration; creation of a hinterland and competition with rival centers; upper-class family continuity; religious life and institutions; political history.

**371, 372. Special Topics (3-6)**
A seminar on a topic of special interest in urban studies. Prerequisite: consent of the program director.

# VI

## An Overview from Past to Present

*"The most fundamental principle of the Colonial League (to which Lehigh belongs) is the concept of the 'student-athlete,' and the firm requirement that our athletes be academically representative of their student bodies."* – Lehigh President Peter Likins.

# VI.

# An Overview from Past to Present

Lehigh University is independent, nondenominational, and coeducational.

Founded in 1865 as a predominantly technical four-year school, the university now has approximately 4,500 undergraduates within its three major units—the College of Arts and Science, the College of Business and Economics, and the College of Engineering and Applied Science—and approximately 1,900 students enrolled in graduate programs offered through the Graduate School in these colleges and in the College of Education. There are undergraduates from nearly every state and U.S. territory and more than forty foreign nations.

The university is primarily situated on the Asa Packer campus on the north slope of South Mountain overlooking Bethlehem, Pennsylvania. Sayre Park, the wooded refuge located toward the top of the mountain, is the setting for many living groups. The residences are reached via winding private roads. Many residential units on campus command a panoramic view of the Lehigh Valley. The Appalachians are visible to the west, with an especially good view from The Lookout on the Packer Campus. Both the tower and dining room in Building A on the new Mountaintop campus afford panoramic views of the Lehigh Valley. The campus at its highest point is 971 feet above sea level.

Because of the unique setting, interesting architectural treatments are possible. Several dwellings and academic buildings are entered from upper levels, such as the third floor.

A substantial portion of the upper level of the Packer Campus is maintained as a nature preserve. The preserve supports deer, squirrels, chipmunks, raccoons, and birds.

Besides the Asa Packer Campus, the university has extensive athletic fields and facilities on the Murray H. Goodman Campus, two miles to the south in the Saucon Valley. The university acquired the Mountaintop Campus at the end of 1986. It links the Asa Packer and Murray H. Goodman campuses and brings total land holdings in Bethlehem to 1,600 acres, nearly double the former total.

The university also operates Stone Harbor Marine Laboratory, near Stone Harbor, N.J. The institute has laboratories and dormitory space for students. It is concerned with the preservation and improvement of the coastal environment.

The board of trustees and university officers have established and enforce policies designed to preserve Lehigh's natural beauty. It is their contention that the environment in which the young adult university student pursues knowledge can make the total educational experience more meaningful, and that the ideal environment is separate and unique from the distractions of the non-academic community.

There are approximately 375 members of the faculty, teaching a total of more than 2,000 course titles (not all of which are offered every semester). Among faculty members who are tenured and to whom the university has a permanent commitment, nearly all hold the doctorate degree (typically Ph.D. or Sc.D.).

In total, there are more than 2,000 employees of the university, making it the second-largest employer in the community.

## History and Purpose

*The principal author of the brief history of Lehigh University that follows, Dr. W. Ross Yates, holds the bachelor of arts and master of arts degrees from the University of Oregon,in his native state. He received the doctor of philosophy degree from Yale University and studied in France on a Fulbright Scholarship. He joined the Lehigh staff in 1955 and served as dean of the College of Arts and Science from 1963 to 1972. Today he is professor emeritus of government, and lives in Oregon.*

When the sound of the last cannon of the Civil War died away, statesmen, educators, and industrial pioneers marshalled the victorious forces of the North and turned their attention to education. They wanted to increase the number of trained scientists, engineers, and other skilled people so they could transform the vast natural resources of the country into a strong and independent national economy.

Asa Packer was one of the industrial pioneers. He built the Lehigh Valley Railroad and controlled a coal-mining empire in the mountains of eastern Pennsylvania. He knew, as did many others, that a strong national economy depended on more than technical skills. It needed above all people broadly educated in the liberal arts and sciences—people who could combine practical skills with informed judgments and strong moral self-discipline. He kept this in mind when founding and endowing Lehigh University.

The site that Packer chose for his university was a railroad junction across the Lehigh River from Bethlehem, a community founded in 1741 by Moravian missionaries. William Bacon Stevens, Episcopal bishop of the Diocese of Pennsylvania and the first president of the university's board of trustees, in 1869 described the origin of the university as follows:

"In the fall of 1864 an interview was requested of me by the Hon. Asa Packer, of Mauch Chunk (now Jim Thorpe), Pa. He came to my house in Philadelphia, and said that he had long contemplated doing something for the benefit of his State, and especially of the Lehigh Valley. From that valley he said he had derived much of the wealth which GOD had given to him, and to the best interests of that valley he wished to devote a portion of it in the founding of some educational institution, for the intellectual and moral improvement of the young men of that region.

"After conversing with him a little while, and drawing out his large and liberal views, I asked him how much money he purposed to set aside for this institution, when he quietly answered that he deigned to give $500,000. At the time of this interview no one in this country, it is believed, had offered in a single sum such an endowment for a literary institution. It was the noblest offering which an American had ever laid on the altar of learning, and more than equaled many royal donations which have carried down the names of kings as patrons of European universities.

"Filled with profound emotions at the mention of such a gift for such an object, I asked the noble donor what specific plans he had dreamed in his own mind in reference to it. His reply was, 'I am not much acquainted with these matters, but you are, and I want you if you will to devise a plan which I can put into effective operation.' I told him that I would make the attempt. I did so. I drew up the outline sketch of such an institution as I thought would give the largest results for the means used, and submitted it in a few weeks to his inspection.

"He examined it with the practical judgment and business habits with which he deals with all great questions, and adopted the scheme as the basis of his future university.

"The first meeting of the Board of Trustees, selected by Judge Packer, met at the 'Sun Hotel,' in Bethlehem, July 27th, 1865, and began to organize the work before them."

The trustees followed several principles in setting up the university. One was that of combining scientific and classical education. They considered both to be practical. The principle carried forward an ideal of the great 17th-Century Moravian educator, John Amos Comenius. A motto taken from the works of Francis Bacon was used to summarize this principle, namely, *Homo minister et interpres naturae*—man, the servant and interpreter of nature, to use a free translation. That motto lives on at Lehigh, being an element in the university seal.

The trustees chose as first president a man whose education and habits expressed this principle, Henry Coppée. They established five schools, including a school of general literature in addition to four scientific schools of, respectively, civil engineering, mechanical engineering, mining and metallurgy, and analytical chemistry.

Another principle upon which the trustees insisted was that of keeping the size of the student body proportionate to the abilities of the faculty to teach them well. The university would admit only as many freshmen each year as it could be assured of providing with the highest quality of education. In the 19th Century the total enrollment never exceeded several hundred students; the size has increased significantly in recent decades, along with the number of faculty members.

The trustees also insisted that Lehigh was to be nondenominational and would have an admission policy based on merit. Competitive examinations were held for applicants for admission. From 1871 to 1891 no tuition was charged, but the national financial crisis at the turn of the century decimated the value of the Lehigh Valley Railroad stock that Packer had given to Lehigh, which was the principal source of income.

At first the student body was entirely male. The contemporary ideological climate would permit nothing else. But around 1916, women were admitted to graduate programs. In 1971, the university opened its undergraduate program to them as well. Today men and women applicants are considered on an equal basis, and in the class that entered in 1986 more than 35 percent of the students were female.

From the first, the students were serious-minded. In 1924, Catherine Drinker Bowen, daughter of president Drinker and later a famous biographer, published a brief *History of Lehigh University*, in which she commented:

"Ask any college professor which brand of boy he would prefer to teach, the cigarette brand or the flannel shirt variety. Right here we offer ten to one the flannel shirts . . . Lehigh still holds to the emblem of the flannel shirt—long may it wave! Engineers come to college to work. A writer in the *Syracuse Post* in 1895 spoke truthfully when he said, 'From the first, Lehigh's characteristic has been her earnestness. It is the boast of her graduates, the inspiration of her students. Men go there to learn to take a useful part in the economy of life'."

The university community was constantly infused with new faculty and students determined to renew and rework the original principles in the light of changing times. The students' ambition and zeal bore fruit; as alumni they carried the university's educational goals into the work of nation-building. And, having received, they gave to perpetuate Lehigh's work of service.

Today, Lehigh University still adheres to Asa Packer's goal of a liberal and scientific education for practical service. Faculty and students work to maintain high quality in instructional programs. Generous support from individuals, foundations, industry, and government help Lehigh to retain high quality of education and faculty while keeping tuition as low as possible. (Tuition covers only a part of the cost of a Lehigh education.)

## Presidents of the University

The presidents of Lehigh University are described and their achievements cited in the following paragraphs. The years in parentheses are those served in the presidency.

**Henry Coppée** (1866-1875). Coppee served as a railroad engineer in Georgia, a captain in the Army during the Mexican War, and taught at West Point and at the University of Pennsylvania before becoming first president in 1866.

Much building was done on the new university campus. A Moravian church on Packer Avenue was remodeled into Christmas Hall; a house for the president was erected on campus; and Packer Hall, the university center, was built.

Coppee lectured in history, logic, rhetoric, political economy, and Shakespeare.

**John McDowell Leavitt** (1875-1880). Leavitt was an Episcopal clergyman who graduated from Jefferson College and taught at Kenyon College and Ohio University. During his incumbency, the university was divided into two schools, General Literature and Technology. As of 1876, a student could receive two engineering degrees by taking a longer course, and beginning in 1877 the master of arts, doctor of philosophy, and doctor of science degrees were established.

Linderman Library rotunda was completed in 1877. Asa Packer died in May, 1879, and Founder's Day was held in his honor the following October.

**Robert Alexander Lamberton** (1880-1893). Lamberton, a graduate of Dickinson College, practiced law in Harrisburg, Pa., and was a university trustee when asked to become president. During his administration, students and the community witnessed the first Mustard and Cheese dramatic presentation.

A gymnasium (now Coppee Hall) was erected, and Chandler Chemistry Laboratory was built, now known as Chandler-Ullmann Hall. Lehigh was also building its reputation for academic excellence; the mechanical engineering department was established in 1881 and the Lehigh chapter of Phi Beta Kappa was founded in 1887.

**Thomas Messinger Drown** (1895-1904). Drown studied medicine at the University of Pennsylvania and went abroad to study chemistry. Thereafter he was professor of chemistry at Lafayette College. In 1895 he assumed the presidency of Lehigh and was greatly interested in furthering the university's development as a technical school.

His first years were difficult ones because the Panic of 1893 decimated the university's stock holdings in the Lehigh Valley Railroad. Nevertheless, Lehigh managed to grow in enrollment, academics, and in physical plant. Williams Hall was completed. The curriculum leading to a degree in arts and engineering was established, as was the department of zoology and biology. New curricula were adopted in metallurgical engineering, geology, and physics.

Drown died in office in 1904. Professor William H. Chandler became acting president.

**Henry Sturgis Drinker** (1905-1920). Drinker, an 1871 Lehigh graduate, was the only university alumnus ever to become president. In 1907, the alumni endowment fund began, the *Lehigh Alumni Bulletin* was first published in 1913, and the Alumni Association was incorporated in 1917.

Drinker, besides being a lawyer, was a mechanical engineer and had been largely instrumental in solving the problems of constructing the two-mile-long Musconetcong Tunnel, an engineering feat that made possible a railroad line between Easton, Pa., and New York City. He started a tradition of businesslike management of university affairs.

During Drinker's years, more buildings were completed: the original section of Fritz Engineering Laboratory, Drown Hall, Coxe Mining Laboratory, Taylor Hall, Taylor Gymnasium and Field House, Taylor Stadium and Lamberton Hall. Drinker's interest in horticulture led to the planting of many rare trees and plants.

A teacher's course and business administration course were begun in 1909 and in 1918 the university was divided into three colleges, liberal arts, business administration, and engineering—the roots of the colleges of today. Army ROTC was established in 1919.

Drinker's daughter, Catherine Drinker Bowen, went on to become a historical writer of note. Her experiences as the daughter of a Lehigh president and occupant of the President's House are recorded in *Family Portrait* (Atlantic Little-Brown).

Drinker resigned in 1920 and Natt M. Emery, vice president, served as chief executive officer until 1922.

**Charles Russ Richards** (1922-1935). Richards took office in 1922. During his presidency, the first graduate degrees were awarded to women. Lehigh faced a shortage of students from 1929 to 1936 as a result of the Depression, but the newly established office of admission, as well as university scholarships, fellowships, and deferred tuition payments, helped to ease the shortage.

Changing concepts of education were evident in several newly organized academic offerings: philosophy, music, psychology, journalism, history, and fine arts. The majors system was instituted as were the senior comprehensive examinations in the Arts College. The placement bureau, a public relations office, and a student health service were organized.

The Alumni Memorial Building—a memorial to the Lehigh alumni who served in World War I—and Packard Laboratory both

were completed in 1925. In the same decade, a major addition to Linderman Library also was completed.

**Clement C. Williams** (1935-1944). Williams, a civil engineer, was president during an era of unprecedented alumni support. Undergraduate enrollment rose to an all-time high, passing 2,000 in 1938. Richards and Drinker residential houses, and the Ullmann building adjoining the Chandler Chemistry Laboratory, were built. Grace Hall, the first arena-type facility of any size on campus, was completed in 1940, the gift of Eugene G. Grace, an 1899 graduate, who headed the board of trustees. A Graduate School implemented the programs in the three colleges. Williams retired in 1944, and the university was without a president for approximately two years.

**Martin Dewey Whitaker** (1946-1960). Dr. Whitaker, who had been director of the Atomic Energy Commission Laboratory at Oak Ridge, Tenn., and had worked in developing the atomic bomb, faced the responsibility of helping the university community readjust to peacetime conditions after World War II.

During his time as president, Lehigh's assets nearly tripled; the endowment more than doubled to $18 million. Many buildings were renovated, and the Dravo House and McClintic-Marshall House residence halls were built. The faculty increased in number by 75 percent and the first endowed distinguished professorships were established.

The Centennial development program was begun in 1959. It raised more than $22 million for faculty salaries and construction that later included Whitaker Laboratory.

An extensive renovation and enlargement project associated with Packer Hall was undertaken in 1957, and, upon completion in 1958, the building became a university center.

Academically, during the Whitaker years 120 departments offered the master's degree and twelve the doctor of philosophy.

Whitaker died in office.

**Harvey A. Neville** (1961-1964). Dr. Neville was the only faculty member ever elected president. His association with the university began in 1927 as an assistant professor of chemistry. During his three-year term as president, the first phase of the Saucon Valley athletic complex was completed, and Sayre Field was opened atop South Mountain. The Center for Information and Computing Science was established.

Dr. Neville, a strong supporter of research who fostered its growth on the campus, died in 1983.

**Deming Lewis** (1964-1982). Willard Deming Lewis became president after a distinguished career as a space engineer and research administrator.

Dr. Lewis comes from a remarkable family that traces its American roots to William Lewis, an Englishman who settled in the Massachusetts Bay Colony in 1640. His great-grandfather and grandfather were presidents of the Lewis Manufacturing Co., a textile firm in Walpole, Mass. Willard Lewis, Deming's father, moved to Augusta, Ga., and eventually became owner of Riverside Mills there.

Deming was admitted to Harvard at age fifteen, but his mother thought him too young to attend. So he waited and entered Harvard at age sixteen, eventually receiving three degrees there, as well as two degrees from England's Oxford University, where he was a Rhodes Scholar in advanced mathematics. At Harvard, Lewis worked with Ted Hunt, the father of high fidelity, writing the equations describing a stylus sliding through a warped groove.

In 1941, Lewis joined Bell Telephone Laboratories, and in 1962 he was one of four executives who initiated Bellcomm, Inc., in Washington, D.C., which engineered systems for the Apollo project that placed the first man on the moon.

Lewis, a Bethlehem resident, holds thirty-three-U.S. patents on such devices as microwave antennas and filter and digital error detection systems.

During the Lewis administration, undergraduate women were admitted in 1971, and the university's visiting committees were established in 1964. New programs included majors in natural science, biology, social relations, geological sciences, environmental science and resource management, and religion studies. Minors for engineering students in such fields as business, history, and social sciences were begun. Interdisciplinary majors such as computer engineering, computing and information science, applied mathematics, management science, American studies, and many others were instituted. Six research centers and seven institutes were established, including the Biotechnology Research Center.

The first phase of the New Century Fund capital campaign yielded $1.1 million more than its goal of $30 million; the second phase, which brought the campaign to a conclusion in 1985, raised more than $100 million.

Construction included the following: Maginnes Hall; Whitaker Laboratory; Mart Science and Engineering Library; the Central Heating and Refrigeration building; Sinclair Laboratory; the Seeley G. Mudd Building and Neville Hall, Rathbone Hall dining room; thirteen fraternity houses, the Centennial I and Centennial II residential complexes; the Trembley Park student apartment complex; the Saucon Village Apartments complex, completion of the acquisition of the Saucon Valley athletic lands and the construction there of the Varsity House, the squash courts, the Philip Rauch Field House and Stabler Athletic and Convocation Center; and Brodhead House, a six-story residence hall. In addition, the restoration of Packer Memorial Church was completed, as well as a million-dollar renovation of Packard Laboratory. Plans were made for the E. W. Fairchild-Martindale Library and Computing Center.

**Dr. Peter Likins** (1982-present). Dr. Likins became eleventh president in 1982. Under his guidance Lehigh continues to seek balanced excellence in undergraduate programs while pursuing focused objectives in graduate study and research.

The Likins presidency has been characterized by achievement and action. In 1986, for example, Lehigh completed construction and implementation of its state-of-the-art telecommunications system, a $20-million-plus project. As a result, virtually all university buildings and residential facilities are wired to allow students and faculty maximum access to information and each other via the voice-and-data telecommunications network. Completion of the network approximately coincided with the dedication in 1985 of the E.W. Fairchild-Martindale Library and Computing Center, which affords to the campus community one of the most automated library facilities available anywhere.

In 1986, a building adjoining the campus, at 200 W. Packer Ave., was named the Harold S. Mohler Laboratory, honoring the former chairman of the board of trustees. The building has been renovated to accommodate the Lehigh programs in manufacturing systems engineering. The high-tech environment gives students access to the latest technology in robotics. The building also houses the industrial engineering department.

In the fall of 1986, a dedication was held for the Sherman Fairchild Center for the Physical Sciences, an outstanding facility encompassing the renovated 1890s-era Physics Building, the contemporary Sherman Fairchild Laboratory, and a new structure linking the two and providing an imposing entrance to physics facilities. The new building includes a 260-seat auditorium.

Also in 1986, the university purchased research facilities and land from Bethlehem Steel Corp. to establish what is now called the Mountaintop Campus, an area southeast of the Packer Campus and north of the Murray H. Goodman Campus, that links both campuses. The acquisition of five buildings and 742 acres at a cost of $18.75 million was the largest real estate transaction in the history of the university. Campus acreage virtually doubled.

Likins led the way in the establishment of the Colonial League in football, effective with the 1986 season. Other schools belonging to the league are Bucknell, Colgate, Davidson, Holy Cross, and Lafayette. The United States Military Academy and Fordham University have agreed in principal to join the Colonial League and the league will expand to 21 sports—11 for men and 10 for women. The league anticipates playing a full competitive schedule beginning with the 1990-91 season. The league represents a commitment by participating schools to the principle of "scholar-athletes," students who are primarily concerned with academic work but who also play football. This principle has been a Lehigh tradition. Eventually, the member schools all will play each other every year, while also including all Ivy League schools in their schedules.

The university completed in 1988 a new stadium for football and other sports on the Murray H. Goodman Campus. Taylor Stadium has been razed to make way for the Rauch Business Center and a future center for the performing arts.

Under Likins, financial support of the university has grown from around $10 million annually to more than $24 million in both 1986-87. In 1986 and 1987, 60 percent of alumni made gifts to

Lehigh, placing Lehigh just behind first-place Dartmouth and just ahead of Princeton in percentage of alumni making gifts. The three schools are the leaders among Ph.D.-granting institutions for which records are kept on a national basis.

Likins was a prime mover in the establishment in 1984 of the Lehigh Valley Center for Jewish Studies, headquartered at Lehigh and serving private colleges in the area, and the establishment of a chair in Judaica based at Lehigh supported by a major gift from Philip and Muriel Berman.

In recent years, Lehigh established a center in the field of integrated circuits, the Center for Innovation Management Studies, the Chemical Process Modeling and Control Research Center, and the Center for International Studies.

A native of California, Likins is relaxed and informal in his interpersonal dealings and has regular personal contact with undergraduates. A former collegiate wrestler of some note (in 1982 he was named to the National Wrestling Hall of Fame), he and members of his family regularly attend Lehigh athletic events.

Likins was substantially involved in the university's designation as home of the North East Tier Ben Franklin Advanced Technology Center, one of four such centers established by the Pennsylvania legislature. The North East Tier center has assisted dozens of fledgling businesses involved in high-technology fields.

Dr. Likins is a distinguished academic administrator, a seasoned educator in engineering, an expert in spacecraft dynamics and control, an author of textbooks in engineering mechanics, a researcher who continues to add to his substantial list of publications, and a consultant to governments and industry.

He earned the B.S. in civil engineering from Stanford University in 1957, the master of science in civil engineering from Massachusetts Institute of Technology the following year, and the Ph.D. in engineering mechanics from Stanford in 1965. He joined Columbia as dean of the School of Engineering and Applied Science in 1976 and was named a provost in 1980. Earlier, he was a development engineer at the Jet Propulsion Laboratory of the California Institute of Technology, and subsequently served as professor and later as associate dean of engineering at the University of California, Los Angeles. He is a fellow of the American Institute of Aeronautics and a member of the National Academy of Engineering.

Dr. Likins and his wife, Patricia, have six children and reside in the President's House.

## *University Campuses*

Lehigh University's three campuses are located in Bethlehem, Pa., and comprise 1,600 acres.

**Asa Packer Campus.** Lehigh's main academic campus, encompassing approximately 360 acres on the north slope of South Mountain overlooking Bethlehem, is a wooded area where most students attend class and live. This is the original campus of the university.

**Murray H. Goodman Campus.** During the 1960s, the university acquired extensive acreage in the Saucon Valley just south of South Mountain. Development of one of the nation's finest collegiate athletic complexes has continued since that time. The 500-acre campus now includes the new Murray H. Goodman Stadium (dedicated in 1988) and other athletic fields, as well as the 6,000-seat Stabler Athletic and Convocation Center, the North East Tier Ben Franklin Advanced Technology Center, the Philip Rauch Field House, and the Varsity House locker facility. The campus is named for a major benefactor, Lehigh alumnus Murray H. Goodman, of West Palm Beach, Fla.

**Mountaintop Campus.** Lehigh bought this campus from Bethlehem Steel Corp. in 1986. It contains 670 acres of forest and a 72-acre research site with five buildings, including a landmark tower building visible for miles around. Acquisition of the facilities—the largest single transaction in Lehigh history—connects the two older campuses. The Mountaintop Campus houses the College of Education; programs in biosciences, biochemistry, biotechnology and chemical engineering, and ATLSS (Advanced Technology for Large Structural Systems) center.

**Stone Harbor Marine Laboratory.** Besides its Bethlehem campuses, the university also operates Stone Harbor Marine Laboratory, located on a 34-acre site adjoining a coastal salt marsh near Stone Harbor, N.J. The institute has laboratories and dormitory space for students. It is concerned with the preservation and improvement of the coastal environment. Many undergraduates study at the institute.

## University Buildings

Lehigh has a major collection of 19th-century buildings designed by such prominent architects as Addison Hutton (1834-1916), Edwart T. Potter (1831-1904) and the firm of Furness and Evans (Frank Furness, 1839-1912).

The university's newer structures include the Goodman Stadium (1988), the Sherman Fairchild Center for Solid-State Studies (1976, 1986), the E. W. Fairchild-Martindale Library and Computing Center (1985), the Stabler Athletic and Convocation Center (1979), the Brodhead House high-rise residential facility (1979), the Seeley G. Mudd Building and Neville Hall in the chemistry complex (1975), and the Philip Rauch Field House (1975)

Altogether, the three campuses contain 130 buildings with more than 3 million square feet of floor space.

In the following list, the first date after the name of each building indicates the year of construction. The second date indicates the year of a major addition.

## *Campus Landmarks*

**Alumni Memorial Building** (1925). This edifice of Gothic design, housing admission and other administrative offices and those of the alumni association, represents a memorial to the 1,921 Lehigh alumni who served in World War I and the 46 who died. The building was designed by Theodore G. Visscher, Class of 1899, and James Lindsey Burley, 1894.

**E. W. Fairchild-Martindale Library and Computing Center** (1985). The high-technology building houses science and engineering holdings and a computer center. Construction was made possible by a major gift from Harry T. Martindale, a1927 Lehigh graduate, and his wife, Elizabeth, daughter of the late Edmund W. Fairchild, founder of a business-publications and communications empire.

**Linderman Library** (1877). The rotunda, designed by Addison Hutton, was built as a gift to the university by founder Asa Packer as a memorial to his daughter, Lucy Packer Linderman. The rotunda is surrounded except on the south by a major addition constructed in 1929. The building houses more than 20,000 rare books and volumes related to the humanities and social science. The Bayer Galleria of Rare Books, made possible by a gift from Curtis F. Bayer, '35, was dedicated in 1985.

**Packer Memorial Church** (1887). The church was the gift of Mary Packer Cummings in memory of her father, founder Asa Packer. It was dedicated on Founder's Day, October 13, 1887. The building was designed by Addison Hutton; the stained-glass window over the main door is attributed to Louis Comfort Tiffany.

Observance of the centennial year took place in 1987.

**President's House** (1868). This 21-room residence, designed by Edward Potter, is the home of university presidents. Dr. and Mrs. Peter Likins and family have occupied the dwelling since 1982.

**Packer Hall, the university center** (1868). When construction of the building began in 1865, a railroad was built to transport stone to the site. The building, designed originally by Potter, was extensively renovated and enlarged in 1958.

The building was constructed at the expense of the founder, who vetoed a plan to erect it of brick. "It will be built of stone," Asa Packer responded.

Today the building houses student lounges, a student cafeteria, a snack bar, a faculty dining room, deans' offices, the journalism department, the student radio station, and a bank office and post office.

## *Academic and Research Facilities*

**Chandler-Ullmann Hall** (1883, 1938, respectively). These adjoining buildings formerly were the William H. Chandler Chemistry Building (designed by Hutton) and the Harry M. Ullmann Chemistry Laboratory. Chandler served as acting university president, 1904 and 1905, and taught chemistry from 1871 to 1906. Ullmann served as chairman of the chemistry department.

The department of art and architecture, division of urban studies, and department of psychology, the Marine Geotechnical Laboratory, the office of Lehigh University Art Galleries and the division of speech and theater are located in Chandler-Ullmann.

**Christmas-Saucon Hall** (1865 and 1872, respectively). Christmas Hall is the university's oldest building. When Asa Packer acquired the South Mountain site for the university in 1865, a Moravian church was being constructed. The newly formed university took over the building and completed it for use in recitations and as a dormitory and chapel. The name Christmas Hall was chosen in keeping with Moravian religious tradition. In 1872, Saucon Hall was constructed a few feet to the east of Christmas Hall. The buildings were connected with the construction of a "hyphen" in 1926. The building houses the department of mathematics and the office of career services.

**Coppée Hall** (1883). The building originally housed classrooms and a gymnasium. It is named in honor of Henry Coppee, first president. Today the building houses the department of modern foreign languages and literature, and The Learning Center.

**Coxe Laboratory** (1910). Originally a mining laboratory, the structure is named for Eckley B. Coxe, pioneer mining engineer and trustee of the university. The building houses the Mechanical Behavior Laboratory and several offices.

**Drown Hall** (1908). The building, designed by Furness and Evans, is a memorial to Thomas M. Drown, president from 1895 to 1904. It is headquarters for the College of Business and Economics until the college moves to the Rauch Business Center in 1990.

**Fritz Engineering Laboratory** (1909, 1955). The laboratory is named for John Fritz, pioneer in the steel industry in the United States and a member of the university's original board of trustees. Fritz provided funds for the original section; a seven-story addition accommodates the university's testing machine, which is capable of applying a five-million-pound load to tension or compression members up to forty feet in length. The hydraulic testing machine is the largest of its kind facility currently in operation in the world. The laboratory is used primarily by the department of civil engineering.

**Johnson Hall** (1955). The building houses the university health service, the counseling service, the chaplain's office, and the parking services office, as well as offices of professors in business and economics. Earle F. "Coxey" Johnson, '07, a director of General Motors Corp. and university trustee, provided funding for the structure.

**Lamberton Hall** (1907). The structure served as the university commons and dining room until the renovation of Packer Hall in 1958. The building honors the memory of Robert A. Lamberton, third president. It houses the music department and related organizations.

**Maginnes Hall** (1970). The multilevel structure is headquarters for the College of Arts and Science and also houses the departments of English, history, government, international relations, classics, and religion studies, as well as the Science, Technology, and Society Program,the Lehigh Valley Center for Jewish Studies, and the Center for International Studies. The university bookstore is located on the ground floor. The building is named for Albert B. Maginnes, '21, who was a lawyer and university trustee.

**Mart Science and Engineering Library** (1968). This structure honors the memory of Leon T. Mart, '13, and his son, Thomas, '51. It operates in conjunction with the E. W. Fairchild-Martindale Library and Computing Center.

**Seeley G. Mudd Building** (1975). This seven-story tower houses the chemistry department. The late Seeley G. Mudd was a California medical doctor. The Seeley G. Mudd Foundation, of Los Angeles, made a major gift toward the building.

**Neville Hall** (1975). This building in the chemistry complex has three auditoriums used for lectures and events. The building is named for Dr. Harvey A. Neville, president from 1961 to 1964, who was a chemist.

**Newman Association Center.** This Victorian structure, until the mid-1970s used as a private residence, was renovated by the Newman Association and serves as a center for students and as a residence for its director, a Roman Catholic chaplain.

**Packard Laboratory** (1929). The structure was the gift of James Ward Packard, Class of 1884, the electrical pioneer and inventor of the Packard automobile who served as a university trustee. The first Packard automobile (1898) is displayed in the lobby. The building is the headquarters for the College of Engineering and Applied Science. It also houses classrooms and laboratories for mechanical engineering and for computer science and electrical engineering. An auditorium accommodates large classes and various events.

**Philosophy Building** (1879). This small building just below Packer Memorial Church was constructed as a porter's lodge. Today it houses the philosophy department.

**Price Hall.** This structure formerly was a brewery named Die Alte Brauerei. In 1912 it was remodeled to serve as a dormitory, and it was named in honor of Henry Reese Price, president of the university board of trustees. It serves as the home of the social relations department.

**Rathbone Hall** (1971). This building's upper level is a major student dining facility, with window walls affording a panoramic view of the Lehigh Valley. The building bears the name of its donor, Monroe Jackson Rathbone, '21, president of the university board of trustees from 1957 to 1973. Rathbone was chairman of the board, Standard Oil Co. (New Jersey), now Exxon Corp., and was a major innovator in the oil industry. The lower level houses the residential services office.

**Sayre Building** (1869). Originally known as the Sayre Observatory, the dome that once housed the telescope can still be seen.

**Sherman Fairchild Center for the Physical Sciences** (1892, 1976, 1986). The center houses classrooms and laboratories for undergraduate and graduate students in physics, and also contains a new 260-seat auditorium. It consists of the original five-story stone structure built in 1892, the Sherman Fairchild Laboratory for Solid-State Studies built in 1976, and an addition built in 1985 with help from the Sherman Fairchild Foundation.

**Sinclair Laboratory** (1970). This facility houses the Center for Surface and Coatings Research, and other research laboratories. It is named for Francis MacDonald Sinclair, and was the gift of his widow, Jennie H. Sinclair.

**Whitaker Laboratory** (1965). This five-story structure with an adjoining two-level classroom-auditorium section honors the memory of Martin Dewey Whitaker, university president from 1946 to 1960. The buildings serve the departments of materials science and engineering and chemical engineering. There are laboratories for high-pressure research and reaction kinetics, nuclear studies, analog computation, process control, high-temperature thermodynamics and kinetics, and fine structures and metallography. The Graduate School office and the office of the vice president for research are located in the building.

**Williams Hall** (1903). This brick structure was the gift of Edward H. Williams, Jr., Class of 1875. Dr. Williams was a professor of mining and geology. The building contains classrooms and laboratories for the departments of biology and of geological sciences. A small greenhouse adjoins the building. The building was

extensively renovated and a fourth story added in 1956 following a fire.

### *Athletic and Convocational Facilities*

**Grace Hall** (1940). The building is named for its donor, Eugene G. Grace, Class of 1899, who was chairman of Bethlehem Steel Corp. and president of the university's board of trustees, 1924 to 1956. The building's lower level seats 3,200 and is used for intramural sports, basketball, wrestling, and women's varsity volleyball as well as concerts and lectures. The upper level accommodates the military science and aerospace studies departments.

**Philip Rauch Field House** (1976). Philip Rauch, '33, made a gift toward the facility. The building has 62,000 square feet of uninterrupted floor space—the equivalent of two football fields—for a variety of athletic activities. It has a six-lane, one-eighth-mile flat track.

**Sayre Field** (1961). Located atop South Mountain, the field is used for intramural sports.

**Stabler Athletic and Convocation Center** (1979). This arena provides seating for 6,000 persons for concerts, spectator sports, and other events. University trustee Donald B. Stabler, '30, made a major financial contribution toward the facility.

**Taylor Gymnasium** (1913 and 1904). This structure was the gift of Charles L. Taylor, Class of 1876, who was a friend and business associate of steel magnate Andrew Carnegie. There are two indoor swimming pools, five basketball courts, and two weight rooms. The department of intercollegiate athletics is housed here.

**Varsity House** (1963). The building houses lockers for varsity teams. It is located on the Murray H. Goodman Campus.

**Wilbur Drama Workshop** (1908). During most of its life, the building served as a power plant. Renovated during the 1970s, it provides performing space for student theatrical productions.

### *Power Facility*

**Central Heating and Refrigeration** (1969). This glass-walled building houses three boilers that can be fired by either oil or gas. Other equipment provides chilled water for air conditioning.

### *Technology Center*

**Ben Franklin Building** (1972). Situated on the Murray H. Goodman Campus in Saucon Valley, the building houses the Lehigh-based North East Tier Ben Franklin Advanced Technology Center.

### *Residential Facilities*

The university is primarily residential in character, with about 85 percent of undergraduates living in facilities on the campus, including university-operated residence halls and independently managed fraternity and sorority houses.

More than 2,000 students live in on-campus residence halls and apartments.

## *Residence Halls*

**Brodhead House** (1979). This structure, the university's first high-rise residential facility, houses 200 students. The six-story building includes student suites on the five upper floors, with a dining facility and lobby on the entrance level. The building is named in memory of Albert Brodhead, a member of the Class of 1888 who died in 1933, leaving 51 Bethlehem properties to his alma mater.

**Dravo House** (1948). This stone edifice is the university's largest residential facility. It bears the name of two brothers, Ralph M. Dravo, Class of 1889, and Francis F. Dravo, Class of 1887, who founded the Dravo Corp., a Pittsburgh-based international construction company. Both men served as university trustees.

**Drinker House** (1940). This stone building honors the memory of Henry S. Drinker, Class of 1871, university president from 1905 to 1920.

**Hillside House.** This building is located off campus at 715 E. Seventh Street and houses upperclass men in 11 apartments.

**McClintic-Marshall House** (1957). This U-shaped stone structure was built in memory of Howard H. McClintic and Charles D. Marshall, both Class of 1888, who founded the McClintic-Marshall Construction Co. The firm was the world's largest independent steel fabricating firm before its acquisition by Bethlehem Steel Corp. in 1931. It built locks for the Panama Canal and constructed the Golden Gate Bridge in San Francisco Bay.

**Richards House** (1938). The building honors the memory of Charles Russ Richards, president of the university from 1922 to 1935. The building is constructed of stone in modified Gothic design.

**Taylor Residential College** (1907, 1984). The U-shaped building is one of the earliest concrete structures ever built. It was the gift of industrialist Andrew Carnegie in honor of his friend and associate, university trustee Charles L. Taylor, Class of 1876. The interior of the building was reconstructed and the exterior refinished prior to the facility becoming Lehigh's first residential college in 1984.

**Trembley Park** (1975). This seven-building undergraduate apartment complex is named in memory of Francis J. Trembley, Lehigh professor and pioneer ecologist.

**Warren Square Complex.** This cluster of four residence halls is located on Warren Square and Summit Street. They are upperclass facilities and are used as special-interest houses.

### *Centennial II complex (1970)*

**Beardslee House.** Dr. Claude G. Beardslee was chaplain from 1931 to 1947.

**Carothers House.** Dr. Neil Carothers was dean of business.

**Palmer House.** Dr. Philip M. Palmer was dean of the arts.

**Stevens House.** The Rt. Rev. William Bacon Stevens, of Philadelphia, was Protestant Episcopal bishop of the Diocese of Pennsylvania and first president of the university board of trustees. He was the principal architect of the university's original academic plan.

**Stoughton House.** Dr. Bradley Stoughton was dean of the engineering college, 1936 to 1939.

**Williams House.** Dr. Clement G. Williams was president of the university, 1935 to 1944.

### *Saucon Village Apartments (1974)*

The five-building garden apartment complex includes housing for married and graduate students, and undergraduates.

**Diamond.** Dr. Herbert M. Diamond, professor emeritus of economics, retired in 1964.

**Gipson.** Dr. Lawrence Henry Gipson, research professor of history, bequeathed his estate to the university to establish the Lawrence Henry Gipson Institute for Eighteenth-Century Studies. Dr. Gipson wrote a monumental 15-volume history, *The British Empire Before the American Revolution.* He won the Pulitzer Prize for volume 10, *The Triumphant Empire: Thunderclouds Gather in the West, 1763-1766.*

**Hartman.** Dr. James R. Hartman was chairman of the department of mechanical engineering and mechanics.

**More.** Dr. Robert P. More, '10, dean of the College of Arts and Science, who also taught German for forty years, bequeathed to the university his $746,000 estate, amassed after investing $3,000 in IBM stock.

**Severs.** Dr. J. Burke Severs, of Bethlehem, is distinguished professor emeritus of English. He is a Chaucerian scholar.

### *Fraternities and Sororities*

The university has a strong fraternity tradition, dating back to 1872. Since the admission of undergraduate women in 1971, several sororities have come into being. Some 1,200 men live in fraternities.

Most of the fraternities have houses located in Sayre Park, while a few others are situated off campus. All are chapters of national fraternities.

An alphabetical listing follows. The date of the founding of the chapter is given in the first column. A second year in the first column indicates reestablishment. The second column lists the date the chapter occupied its present house; any additional date indicates the most recent addition or major renovation.

| | | |
|---|---|---|
| Alpha Chi Rho | 1918 | 1968 |
| Alpha Epsilon Pi | 1979 | 1978 |
| Alpha Sigma Phi | 1929 | 1961 |
| Alpha Tau Omega | 1886 | 1966 |
| Beta Theta Pi | 1891 | 1968 |
| Chi Phi | 1872 | 1922, 1968 |
| Chi Psi | 1893 | 1916, 1955 |
| Delta Chi | 1952 | 1968 |
| Delta Phi | 1884 | 1963 |
| Delta Tau Delta | 1874, 1985 | 1959 |
| Delta Upsilon | 1885 | 1968 |
| Kappa Alpha | 1894 | 1961 |
| Kappa Sigma | 1900 | 1973 |
| Lambda Chi Alpha | 1926 | 1973 |
| Phi Delta Theta | 1876 | 1919, 1963 |
| Phi Sigma Kappa | 1901 | 1957, 1970 |
| Pi Kappa Alpha | 1929 | 1903 |
| Pi Lambda Phi | 1915 | 1965 |
| Psi Upsilon | 1884 | 1909, 1966 |
| Sigma Alpha Mu | 1923 | 1966 |
| Sigma Chi | 1887 | 1953 |
| Sigma Nu | 1885 | 1970 |
| Sigma Phi | 1887 | 1950, 1961 |
| Sigma Phi Epsilon | 1907 | 1963 |
| Tau Epsilon Phi | 1963 | 1964 |
| Theta Chi | 1942 | 1964 |
| Theta Delta Chi | 1884 | 1937, 1967 |
| Theta Xi | 1904 | 1967 |
| Zeta Psi | 1973 | 1973 |

There are six sororities. All are nationally affiliated.

The sororities are listed with year of establishment at Lehigh in the first column, and year of moving into the Centennial I complex in the second column. Some 280 women live in sorority houses.

| | | |
|---|---|---|
| Alpha Gamma Delta | 1975 | 1985 |
| Alpha Phi | 1975 | 1984 |
| Gamma Phi Beta | 1975 | 1985 |
| Delta Gamma | 1982 | 1987 |
| Alpha Omicron Pi | 1983 | 1986 |
| Kappa Alpha Theta | 1984 | 1986 |

### *Centennial I complex (1965)*

**Congdon House.** Dr. Wray H. Congdon served as dean of students, dean of the graduate school, and special assistant to the president. Alpha Phi sorority is housed in Congdon.

**Emery House.** It is named for Dr. Natt M. Emery, who was vice president and controller. Gamma Phi Beta sorority is housed in Emery.

**Leavitt House.** The Rev. Dr. John McD. Leavitt was the second president, 1875 to 1879. Alpha Gamma Delta sorority is housed in Leavitt.

**McConn House.** C. Maxwell McConn was dean of the university from 1923 to 1938. Alpha Omicron Pi sorority is housed in McConn.

**Smily House.** Dr. E. Kenneth Smiley served as vice president from 1945 to 1964. Kappa Alpha Theta sorority is housed in Smiley.

**Thornburg House.** Dr. Charles G. Thornburg was professor and head of the department of mathematics, 1895 to 1923. His grandson, Dick Thornburgh, completed his second term as governor of Pennsylvania at the end of 1986. Delta Gamma sorority is housed in Thornburg.

# In Bethlehem, An Educational Tradition

Lehigh University shares in the historical heritage of Bethlehem, even though, having been founded in 1865, it is a relative newcomer. The fact that Lehigh was established in Bethlehem reflects the tradition of education established by the community's first settlers thirty years before the founding of the nation.

The first Moravians were among the many German religious sects that came to the New World, and especially to Pennsylvania, during the early 1700s. But unlike William Penn, who established his *sylvania* as a new land where he might hold his Quaker beliefs away from England's oppression, the Moravians came as missionaries with the intent of converting the Indians to Christianity. For this purpose they settled the Lehigh Valley.

The early Moravians were industrious. Their first building, the Gemein Haus (community house) was completed in 1741. This building stands today, one of thirty-nine remarkably preserved pre-Revolutionary War buildings constructed by the Moravian settlers and in continuous use ever since by the Moravian community. Many of these buildings are located on Church St., west of the City Center; industrial buildings are located in the 18th Century Industrial Area in the Monocacy Creek valley west of the business district.

The leader of the Moravians was Count Nicholas von Zinzendorf of Dresden. He arrived in the settlement in time for their observance of Christmas Eve in 1741 and gave the settlement the name Bethlehem—"house of bread".

The settlers built high-quality structures of stone, demonstrating principles of engineering that were not generally used elsewhere. They were interested in music, and established the first symphony orchestra in America. In 1748, the settlement had a fourteen-man orchestra. The community's first organ was built in 1757 by John Gottlob Klemm. The musical tradition, including the trombone choir, continues today, perhaps most visibly in the Bach Choir of Bethlehem, whose yearly Bach Festival is held in the university's Packer Memorial Church. In 1985, the 300th anniversary of the birth of Johann Sebastian Bach was observed.

Zinzendorf envisioned Bethlehem as the center for manufacturing; outlying Moravian settlements, such as Nazareth, Pa., would be primarily devoted to agriculture. On October 15, 1742, a large barn was "raised" with the help of most of the residents. Three months later a grist mill at the community spring produced the first flour. In 1758, the Sun Inn was built along Main St., a haven for travelers. Reconstruction of the picturesque inn was completed in 1982, and it now operates as a community center and public dining facility.

Zinzendorf's determination that Bethlehem would be a major industrial center was assisted by the completion in 1755 of the water works, the first public utility in the New World.

The Moravian dedication to education was an extension of the philosophy of John Amos Comenius, who had written, "Everyone ought to receive a universal education." The Moravian educational institutions that continue today, including Moravian College, stem from this tradition.

The Moravians, although avowedly opposed to war, found their community pressed into service as a hospital when Washington's

troops bivouacked at Valley Forge during the winter of 1777-78. Washington came to the community once, and many other Continental Army officers were visitors.

The Sun Inn was also used as a hospital during the war; among its patients was an aristocratic renegade from France, Marie Joseph Paul Ives Gilbert Motier, the Marquis de la Fayette. Lafayette had come to assist the Continental Army aboard his own ship, the "Victory." Fifty years later a college in Easton was named in his honor and it became Lehigh's traditional football rival.

The first bridge across the Lehigh River was built in 1794. It was replaced in 1816, but the latter was destroyed by a flood in 1841. In 1759, the turnpike (toll road) over South Mountain, generally along the route of the present Wyandotte St. hill, was opened. The present Hill-to-Hill Bridge was built some fifty years ago.

**"Black gold."** During the late 18th Century, anthracite was found in the mountains north of the Lehigh Valley. In 1818, the Lehigh Coal Co. and the Lehigh Navigation Co. were formed, one to mine the anthracite on the upper Lehigh River, the other to transport it down river to metropolitan markets.

The Lehigh River was difficult to navigate. Consequently, in 1829 the Lehigh Canal was completed from Mauch Chunk (now Jim Thorpe), through Bethlehem to Easton, where it connected with the Delaware Canal. During the 1840s, iron mines were opened in the area, and several blast furnaces, fueled by coal, were in operation. Zinc ore, was found in neighboring Upper Saucon Township. In the 1850s Asa Packer built the Lehigh Valley Railroad. These origins eventually led to the heavy industry that continues in the Lehigh Valley today.

When Asa Packer founded Lehigh University in 1865, one of his objectives was to make possible broadly based education for young people of the region, combining the technical skills needed to run the flourishing industry of the Lehigh Valley with a liberal education.

In addition to its role as a steel-making center, Bethlehem today is a major tourist attraction. The Moravian community sets up an elaborate nativity scene and the entire city is decorated with lighting during the holiday period. The Moravian tradition of a single candle (now electric) in each window is widely observed.

Atop South Mountain is a steel tower known as the Star of Bethlehem. During the holiday period, the star's hundreds of bulbs create a 95-foot-high star that can be seen for many miles. The star was the gift to the community of Marion Brown Grace, wife of Eugene Gifford Grace, the steel magnate and president of the university board of trustees.

The community of Bethlehem has a population of approximately 78,000 persons with segments from a variety of nations who retain traditions of their country of origin.

Bethlehem's principal employer is Bethlehem Steel Corp. The corporation maintains a manufacturing facility and corporate headquarters in Bethlehem. A number of high-technology firms also operate in the Lehigh Valley, most notably Air Products and Chemicals, Inc., and AT&T Technologies.

There are five principal independent colleges in the Lehigh Valley besides Lehigh. They are Lafayette, Allentown College of St. Francis de Sales, Moravian, Muhlenberg, and Cedar Crest. A cooperative program is maintained that allows cross-registration for courses as well as shared cultural events. There are also two community colleges in the area.

In August 1984, Bethlehem held its first Musikfest, a 10-day annual festival that features a variety of musical performances and ethnic foods. An instant success, Musikfest was the brainchild of Jeffrey A. Parks, a lawyer and 1970 Lehigh graduate.

# VII

## Administration, Faculty, and Staff

*"I expect our young faculty to learn how to become beautiful teachers and successful researchers as well, or I expect them to find employment in a college or university less demanding of their commitment."* – Lehigh President Peter Likins.

# VII.

# Administration, Faculty and Staff

This section lists the people whose talents and abilities constitute the university's most important resource. Members of the board of trustees contribute their expertise to establish the policies of the university. Also listed are the administration, members of the faculty and staff, and the members of the visiting committees who help to keep courses of instruction current and of maximum value to the students and prospective employers.

## Board of Trustees

When the year of the degree is listed, the degree was awarded by Lehigh University.

### *Officers of the Board*

Edward G. Uhl, chairman
John W. Woltjen, corporate secretary and treasurer
Elmer W. Glick, honorary secretary

### *Members of the Board*

Dexter F. Baker, B.A. in M.E. '50, M.B.A. '57, Allentown, Pa., president and CEO, Air Products and Chemicals Inc.

Philip J. Berg, B.S. in M.E. '44, Sewickley, Pa., retired executive vice president, Dravo Corp.

Gerald E. Berger, B.S. '71, Lansdale, Pa., assistant treasurer of risk management, Conrail.

James M. Bridgman, B.S. '50, New Canaan, Conn., retired program manager, employee relations for Far East, IBM World Trade Americas/Far East.

William L. Clayton, B.S. '51, Short Hills, N.J., executive vice president, E. F. Hutton & Co.

Theodore L. Diamond, B.S. '37, M.B.A., New York City, president, T.L. Diamond Co., Inc.

John Diebold, B.S. Swarthmore, engineering degree U.S. Merchant Marine Academy, M.B.A. Harvard, New York City, N.Y., president and chairman, The Diebold Group.

William B. Eagleson, Jr., B.S. '49, M.B.A., Malvern, Pa., retired chairman, Mellon Bank Corp., Philadelphia

Peter J. Fioretti, B.S. '84, partner, Waterfront Invest, Hoboken.

William O. Fleckenstein, '49, Bethlehem, Pa., retired vice president, Bell Communications Research

Murray H. Goodman, B.S. '48, chairman, The Goodman Group, Palm Beach, Fla.

Milton H. Grannatt, Jr., B.S. '39, Trenton, N.J., chairman, Fell & Moon Co.

William C. Hittinger, B.S. '44, Eng.D. '83, Summit, N.J., retired executive vice president, research and engineering, RCA Corp.

Ronald R. Hoffman, B.S. '54, Pittsburgh, Pa.,vice president, Aluminum Company of America.

Walter S. Holmes, Jr., B.S. '41, M.B.A., Ocean City, N.J., retired chief executive officer and chairman, C.I.T. Financial Corp.

Peter Likins, university president/trustee ex officio.

Eugene Mercy, Jr., B.S. '59, New York City, partner, Goldman Sachs & Co.

Sherri L. Myers, B.S. '84, Cincinnati, OH, chemical engineer, The Proctor & Gamble Co.

Philip R. Peller, B.S. '60, Glen Head, N.Y., partner, Arthur Andersen & Co.

Kirk P. Pendleton, B.A. '63, B.S. '64, Huntingdon Valley, Pa., president, Cairnwood, Inc.

Joseph R. Perella, B.S. '64, M.B.A., New York City, partner, Wasserstein, Perella & Co., Inc.,, New York.

Frank C. Rabold, B.S. '39, Eng.D. '70, Saylorsburg, Pa., retired manager of corporate services, Bethlehem Steel Corp.

James R. Rice, B.S. '62, M.S. '63, PhD. '64, on sabbatical leave for a year from engineering science and geophysics dept., Harvard University, currently at California Institute of Technology.

Stanley M. Richman, B.S. '55, Short Hills, N.J., vice president, Lightning Electric Co.

Augustus A. Riemondy, '41, Hershey, Pa., retired assistant to the president, Hershey Foods Corp.

C. Keith Rust, B.S. '57, Bethlehem, Pa., president, Roland & Roland Inc.

Edwin F. Scheetz, Jr., B.S. '54, Pittsburgh, Pa., chairman, Scheetz, Smith & Co., Inc.

Richard M. Smith, B.S. '48, Macungie, Pa., retired vice chairman, Bethlehem Steel Corp.

Donald B. Stabler, B.S. '30, M.S. '32, LL.D. '74, Harrisburg, Pa., chairman, Stabler Companies Inc.

James B. Swenson, B.B.A. '59, Wellesley, Mass., partner, Price Waterhouse.

Edward G. Uhl, B.S., '40, Sc.D. '74, Trappe, Md., retired corporate chairman of the board, Fairchild Industries.

Ronald H. Vaughn, B.S. '59, Doylestown, Pa., President, NEAPCO.

Joseph M. Workman, B.S. '53, B.S. '54, Bethlehem, Pa., manager of business planning, Bethlehem Steel Corp.

William E. Zeiter,B.A. '55, B.S. '56, J.D. '59, Philadelphia, Pa., partner, Morgan, Lewis and Bockius.

### *Honorary Trustees*

Morgan J. Cramer, '28, Fountain Hills, Ariz., retired president, P. Lorillard and Co.

Lee A. Iacocca, B.S. '45, M.S., LL.D., Eng.D. '69, Bloomfield Hills, Mich., chairman and chief executive officer, Chrysler Corp.

Edmund F. Martin, B.S., Eng.D., LL.D., LL.D. '66, Bethlehem, Pa., retired chairman of the board and chief executive officer, Bethlehem Steel Corp.

Robert H. Riley, Jr., B.S. '35, Towson, Md., retired director, Black and Decker, Inc.

S. Murray Rust, Jr., B.S., in M.E. '34, Orleans, Mass., retired chairman of the board, Rust Engineering Co.

### *Corporate Members Emeriti*

C. Lester Hogan, B.S., M.S. '47, Ph.D. '50, A.M., Eng.D., D.Sc., Eng.D. '71, Atherton, Calif., retired consultant to the president, Fairchild Camera and Instrument Corp.

Leonard M. Horton, B.S. in Bus. Ad. '28, LL.D. '65, Short Hills, N.J., retired chairman of the board, Aubrey G. Lanston & Co., Inc.

Kenneth L. Isaacs, M.E. '25, LL.D., '65, Boston, retired chairman of the board, Massachusetts Investors Trust

Frank L. Magee, E.E. '17, Eng.D. '56, Stahlstown, Pa., retired chairman of the executive committee, Aluminum Company of America

Ivor D. Sims, B.S. in Bus. Ad. '33, LL.D. '70, Bethlehem, Pa., retired executive vice president, Bethlehem Steel Corp.

The Rt. Rev. Dean T. Stevenson, B.A., '37, S.T.B., M.A. '49, D.D., Harrisburg, Pa., retired bishop of the Episcopal Diocese of Central Pennsylvania.

### *Committees of the Board*

**Executive committee.** Mr. Uhl, chairman; the Messrs. Hittinger, Mohler, Pendleton, Rabold, Smith, and Stabler, members.

**Academic affairs committee.** Mr. Hittinger, chairman; Mr. Stabler, vice chairman; the Messrs. Diamond, Fleckenstein, Hoffman, Mercy, Swenson, and Bishop Stevenson, members

**Audit committee.** Mr. Holmes, chairman; Mr. Smith, vice chairman; the Messers. John B. O'Hara, Peller and R. H. Vaughn, members.

**Development and University Relations committee.** Mr. Stabler, chairman; Mr. Clayton, vice chairman; the Messrs. Diamond, Richard H. Francis, Goodman, Sean H. Kelly, Mercy, Mohler, Perella, R. M. Smith and J. B. Swenson, members.

**Finance committee.** Mr. Eagleson, chairman; Mr. Pendleton, vice chairman; the Messrs. Clayton, Francis, Holmes, James N. Land, Jr., Perella, and William D. Washychyn, members.

**Investment subcommittee.** Mr. Pendleton, chairman; the Messrs. Clayton, Francis, Land, Perella, and Washychyn, members.

**Nominating committee.** Mr. Uhl, chairman; Mr. Mohler, vice chairman; the Messrs. Donald H. Bott, Paul J. Franz, Jr., Hittinger and Pendleton, members.

**Physical planning and plant committee.** Mr. Rabold, chairman; Mr. Richman, vice chairman; the Messrs. Baker, Berg, Bridgman, Goodman, Riemondy, and Gregory D. Schulze, members.

**Research committee.** Mr. Fleckenstein, chairman; the Messrs. Diamond, and Hoffman,members.

**Student affairs committee.** Mr. Scheetz, chairman: the Misses Marson and Lisa A. Palazzi; the Messrs. Peter J. Fioretti, Grannatt, Jr., Peller, Vaughn and Workman, members.

# Members of the Administration

Educational information (degrees earned and colleges and universities attended) may be found in the alphabetical listing that follows in this section. The highest degree earned is given here.

All offices, unless otherwise noted, are located at Bethlehem, Pa. 18015; the area code, unless otherwise noted, is (215).

### *Offices of the President and Provost*

Alumni Memorial Building 27; 861-3155

Peter Likins, Ph.D., president
David A. Sanchez, Ph.D., provost and vice president
Marsha A. Duncan, M.S., vice president for student affairs
Michael G. Bolton, M.B.A., vice president for development and university relations
Joseph I. Goldstein, Sc.D., vice president for graduate studies and research
Eric V. Ottervik, Ph.D., vice president for academic services
John W. Woltjen, B.S., vice president for administration and treasurer
Patti T. Ota, Ph.D., associate provost
Linda T. Seeloff, M.Ed., director of institutional studies
Mary I. Malone, B.A., secretary to the president

### *Academic Officers*

Richard W. Barsness, Ph.D., dean, College of Business and Economics
Alan W. Pense, Ph.D., dean, College of Engineering and Applied Science
James D. Gunton, Ph.D., acting dean, College of Arts and Science
David A. Thomas, Sc.D., dean of graduate studies
Alden J. Moe, Ph.D., dean, College of Education

George E. Kane, P.E., associate dean, College of Engineering and Applied Science
G. Mark Ellis, Ph.D., associate dean, College of Arts and Science
Judith N. Lasker, Ph.D., associate dean, College of Arts and Science
Joseph P. Klein, M.B.A., assistant dean, College of Business and Economics

## *Offices and Resources*

In this section, only the principal officers, are listed. For degree information, consult the alphabetical listing that follows.

### *Administrative Systems*

E.W. Fairchild-Martindale Library and Computing Center 8; 758-3010

Roy A. Gruver, director

### *Admission*

Alumni Memorial Building 27; 758-3100

Samuel H. Missimer, director

### *Admission*

Alumni Memorial Building 27; 758-3100

Samuel H. Missimer, director

### *Alumni Association*

Alumni Memorial Building 27; 758-3135
Donald H. Bott, executive director

### *Art Galleries*

Chandler-Ullmann Hall 17; 758-3615
Ricardo Viera, director

### *Athletics and Recreation*

Taylor Gymnasium 38; 758-4300
John C. Whitehead, director

### *Auxiliary Services*

Rathbone Hall 63; 758-3514
Barbara L. Kreppel, director

### *Bookstore*

Maginnes Hall 9; 758-3375
Robert W. Bell, director

### *Budget*

Alumni Memorial Building 27; 758-4202
James A. Tiefenbrunn, director

### *Bursar*

Alumni Memorial Building; 758-3160
Joseph Petronio, bursar

### *Career Services*

Christmas-Saucon Hall 14; 758-3710
Eugene R. Seeloff, director

### *Mailing and Printing Services*

Alumni Memorial Building 27; 758-3110
Wayne S. Hoffman, director

### *Chaplaincy Services*

Johnson Hall 36; 758-3877
The Rev. Hubert L. Flesher, university chaplain and professor of religion studies

### *Community Relations*

Building A, Mountain Campus; 758-3885
James W. Harper, director

### *Computing and Communication Services*

400 Linderman 30; 758-4750
Bruce O. Fritchman, assistant vice president

### *Computing Center*

E.W. Fairchild-Martindale Library and Computing Center 8A; 758-3830
William R. Harris, director

### *Conference Services*

Rathbone 63; 758-5306
George J. Warden, coordinator

### *Continuing Education and Summer Sessions*

219 Warren Square; 758-3935; 758-3966
James A. Brown, director

### *Controller*

Alumni Memorial Building 27; 758-3140
F. Robert Huth, Jr., controller

### *Counseling Service*

Johnson Hall 36; 758-3880
Ian T. Birky, director

### *Dean of Students*

Packer Hall, University Center 29; 758-4156
John W. Smeaton, assistant vice president and dean of students
Terrence M. Curran, associate dean of students
Mark H. Erickson, associate dean of students
Jennifer Volchko, associate dean of students

### *Development*

Alumni Memorial Building 27, Bethlehem, Pa. 18015 (215) 758-3120
Michael G. Bolton, vice president for development and university relations
John T. Fulton, assistant vice president for development

### *Facilities Services*

461 Webster St.; 758-3970
Anthony J. Corallo, assistant vice president
Gary A. Falasca, director of physical plant
Patricia A. Chase, director, office of physical planning

### *Financial Aid*

Alumni Memorial Building 27; 758-3181
William E. Stanford, director

### *Forum*

Packer Hall, University Center 29; 758-4190
Charles B. Sclar, co-chairperson (1988-89)
Jorge I. Segovia, co-chairperson (1988-89)

### *Fraternity Management Association*

Johnson Hall 36; 861-3888
Richard M. Jones, M.B.A., executive director

### *Health Center*

Johnson Hall 36; 758-3870
Susan C. Kitei, M.D., acting director

### *Human Resources (Personnel)*

622 Brodhead Ave.; 758-3900
Edward R. Maclosky, director

### *Institutional Purchasing*

404 Adams St.; 758-3840
Barry L. Gaal, assistant vice president for business services

### *Internal Audit*

Alumni Memorial Building 27; 758-5012
Robert J. Eichenlaub, director

### *International Programs*

Packer Hall, University Center 29; 861-4152

Marcy Cohen, Ed.D., coordinator for international students and visitors

### *The Learning Center*

Coppee Hall 33; 758-3098
Edward E. Lotto, director

### *Libraries*

E.W. Fairchild-Martindale Library and Computing Center 8; 758-3025
Berry G. Richards, director
Lynn K. Milet, director of media services

### *Microcomputer Store*

Sayre Building 26; 758-4606
Robert Kendi, manager

### *Personnel*

(See Human Resources)

### *University Police*

Packer Hall, University Center 29; 758-4200
Eugene Dax, chief

### *Public Information*

(See University Communications)

### *University Publications*

(See University Communications)

### *University Communications*

Media Relations, 436 Brodhead Ave.; 758-3170
Public Relations, University Relations, Alumni Memorial Building 27; 758-4588
Sports Information, 436 Brodhead Ave.; 758-3174
University Publications, Linderman Library 30; 758-3015

Glenn Airgood, director

### *Registrar*

Alumni Memorial Building 27; 758-3200
Bruce S. Correll, registrar

### *Office of Research and Sponsored Programs*

203 E. Packer Ave.; 758-3020
Richard B. Streeter, director

### *Vice President for Graduate Studies and Research*

Whitaker Laboratory 5; 758-4210
Joseph I. Goldstein, vice president

### *Residential Services*

Rathbone Hall 63; 758-3500
David M. Joseph, director

### *Risk Management*

616 Brodhead Ave.; 758-3899
Thomas J. Verbonitz, director

### *Student Affairs*

Alumni Memorial Building 27; 758-3890
Marsha A. Duncan, vice president
John W. Smeaton, assistant vice president and dean of students
Joseph D. Sterrett, assistant vice president

### *Telecommunications*

Linderman Library 30; 861-3004

A. Edward Csongradi, M.S., director
Kristine J. Ottervik, B.A., manager of operations
Debra F. Gehringer, B.S., telecommunications analyst

### *Transportation Services*

Murray H. Goodman Campus 126; 758-4410
Christopher J. Christian, manager

### *Treasurer*

Alumni Memorial Building 27; 758-3180
John W. Woltjen, vice president for administration and treasurer
Richard H. Sanders, assistant vice president for financial services

### *Ben Franklin Advanced Technology Center*

125 Goodman Drive, Bethlehem, Pa. 18015; (215) 758-5200
Mark S. Lang, executive director

### *Manufacturing Services Extension Center*

301 Broadway, Bethlehem, Pa. 18015; (215) 758-5599
Edith D. Ritter, executive director

# Faculty and Staff; Emeriti

The first date after the name is the date of appointment to continuous service on the Lehigh faculty or staff; the second date, when the first fails to do so, indicates the date of appointment to the present professional rank. Where the name of the institution awarding a high-level degree is not given, the institution is the same one that awarded the previous degree listed.

P.E. indicates certification as a professional engineer; CPA indicates certified public accountant. A.P.R. indicates accreditation by Public Relations Society of America. A.T. C., means certified athletic trainer.

## A

John H. Abel, Jr. (1985), professor of biology. B.A., Wooster, 1959; M.A., Brown, 1964; Ph.D., 1966.

Ifeanyi Achebe (1985), assistant professor of law and business. B.A., Howard, 1969; J.D., 1971; LL.M., New York, 1973.

John W. Adams (1965, 1969), associate professor of industrial engineering. B.S., Nebraska, 1952; Ph.D., North Carolina, 1962.

Karen A. Adams (1980, 1986), assistant director of intercollegiate athletics and head coach of women's tennis. B.S., Temple, 1965.

Mary E. Adams (1988), research associate, E.P.I. Ph.D., University of Sydney, Australia, 1988.

R. Nicholas Adams (1978, 1984), associate professor of art and architecture. A.B., Cornell, 1970; A.M., New York, 1973; Ph.D., 1977.

Christina Le Ager (1981), research engineer, College of Education. B.A., Temple, 1978; M.Ed., Lehigh, 1982.

Glenn Airgood (1987), director of communications, university relations. B.S., Lehigh, 1968.

Daniel Albright (1988), child development specialist, Centennial School. B.S., Kutztown, 1983.

Jack A. Alhadeff (1982, 1985), professor and head of biochemical sciences. B.A., Chicago, 1965; Ph.D., Oregon Medical School, 1972.

Eugene M. Allen (1967, 1982), professor emeritus of chemistry, B.A., Columbia, 1938; M.S., Stevens Inst. of Tech., 1944; Ph.D., Rutgers, 1952.

Judith K. Allio (1976, 1984), software librarian, Computing Center. AD Bus., Morehead State (Kentucky), 1969.

Carlos J. Alvare (1984), professor emeritus of art and architecture. B. Arch., Yale, 1947; M.C.P., Pennsylvania, 1954; M. Arch , Yale, 1973.

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David J. Anastasio (1986, 1987), assistant professor of geological sciences. B.A., Franklin and Marshall, 1980; M.A., Johns Hopkins, 1984; Ph.D., 1987.

N. Craig Anderson (1966, 1968), associate director and business/ticket manager, intercollegiate athletics and recreation. B.S., Lehigh, 1960; M.S., Southern Illinois, 1964.

William R. Anderson, Jr. (1981), research spectroscopist, chemistry. B.S., San Jose State, 1959.

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Ray L. Armstrong (1946, 1975), professor emeritus of English. B.A. Williams, 1930; B.A., Oxford, 1932; M.A., 1936; Ph.D., Columbia, 1941.

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Lloyd W. Ashby (1966, 1971), professor emeritus of education. A.B., Hastings (Nebraska), 1927; M.A., Columbia Teachers, 1935; Ed.D., 1950.

Edward F. Assmus, Jr. (1966, 1970), professor of mathematics. B.A., Oberlin, 1953; M.A., Harvard, 1955; Ph.D., 1958.

Betzalel Avitzur (1964, 1968), professor of materials science and engineering and director of Institute for Metal Forming. B.S., Israel Inst. of Tech., 1947; Dip., 1949; M.S., Michigan, 1956; Ph.D., 1961.

Lesa Ayers-Kukoda (1988), staff writer/editor. B.A., Shippensburg College, 1977.

## B

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James C. Baker (1979), programmer/analyst, administrative systems, A.A., Northampton Community College, 1979.

Mary Kay Baker (1986), assistant dean of students. B.A., College of St. Rose, 1981; M.A., Syracuse, 1984.

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Joyce Barker (1984, 1988), administrative associate, B.A., New York State University - Cortland, 1970.

Thoburn V.Barker (1953, 1984), professor emeritus of speech. B.A., Speech, Ohio Wesleyan, 1943; M.A., Columbia, 1951.

Henri J. Barkey (1987), assistant professor of international relations. B.Sc., City University (London), 1975; M.Sc., University College (London), 1976; Ph.D., Pennsylvania, 1984.

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Robert F. Barnes, Jr. (1965, 1976), professor of philosophy; professor of computer science. B.S., M.I.T., 1957; M.A., Dartmouth, 1959; Ph.D., California-Berkeley, 1965.

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Donald D. Barry (1963, 1970), University Professor of government. B.A., Ohio, 1956; M.A., Syracuse, 1959; Ph.D., 1963.

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Douglas L. Brown (1986), research associate, chemistry. B.S., Bridgewater, 1980.

Forbes T. Brown (1970, 1983), head of dynamic systems and professor of mechanical engineering and mechanics. B.S., M.I.T., 1958; M.S., 1958; Mech.E., 1959; Ph.D., 1962.

James A. Brown (1977, 1985), director of continuing education and summer sessions. B.A., Knox, 1965; M.A., George Washington, 1967; Ph.D., Virginia, 1972.

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Josef M. Brozek (1959, 1979), research professor emeritus of psychology. Ph.D., Charles (Prague), 1937.

Arthur W. Brune (1952, 1983), professor emeritus of civil engineering. B.S., Missouri-Rolla, 1941; M.S., 1946; Ph.D., Penn State, 1952.

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Barbara Bunn (1987), teacher, Centennial School. B.S., Delaware, 1983.

Natt B. Burbank (1964, 1971), professor and assistant dean emeritus, School of Education. A.B., Vermont, 1925; M.A., Columbia, 1931; LL.D., Vermont, 1963.

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## C

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Clarence B. Campbell (1947, 1957, 1974), dean emeritus of residence. B.A., Temple, 1937; M.A., Lehigh, 1947.

Donald T. Campbell (1982), University Professor of social relations and psychology. A.B., California-Berkeley, 1939; Ph.D., 1947.

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Hugo S. Caram (1977, 1986), professor of chemical engineering. B.S., Buenos Aires (Argentina), 1967; Ph.D., Minnesota, 1977.

Bobb Carson (1971, 1983), chairperson and professor of geology. B.A., Carleton, 1965; M.S., Washington, 1967; Ph.D., 1971.

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Amitabha Chakrabati (1988), Ph.D., University of Minnesota, 1987.

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Robin Cohen (1988), child development specialist, Centennial School. B.S., Lehigh, 1984.

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Colleen S. Cole (1986), model teacher, Centennial School. B.S., Kutztown, 1986.

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John N. Covert (1967), assistant director of intercollegiate athletics and recreation, varsity cross country and track coach. B.S.Ed., Buffalo State, 1953.

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Stephen H. Cutcliffe (1976, 1987), director of science, technology, and society program; Lehigh University Press; and Technology Studies Resource Center. A.B., Bates, 1968; M.A., Lehigh, 1973; Ph.D., 1976.

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## D

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## I

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## W

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## Y

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## Z

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# Research Organizations/ Directors and Staff

Directors and staff members of the university's research centers and institutes are listed. Complete degree information may be found in the faculty and staff alphabetical listings. In some cases, areas of research interest are given.

All addresses are Bethlehem, Pa. 18015, and the area code is (215).

### *Bioprocessing Institute*

Mountaintop Bldg. 111; 758-5428

Janice A. Phillips, Ph.D., director; Marvin Charles, Ph.D.; James T. Hsu, Ph.D.; Arthur E. Humphrey, Ph.D.

### *Center for Design and Manufacturing Innovation*

H.S. Mohler Laboratory #200; 758-4114

Betzalel Avitzur, Ph.D.; Russell E. Benner, Ph.D., P.E.; Glenn Blank, Ph.D.; Forbes T. Brown, Sc.D.; D. Richard Decker, Ph.D.; Richard Denton, Ph.D.; Fazil Erdogan, Ph.D.; Bruce D. Fritchman, Ph.D.; Christos Georgakis, Ph.D.; Samuel L. Gulden, M.A.; Ronald J. Hartranft, Ph.D.; Donald J. Hillman, Ph.D.; Ralph J. Jaccodine, Ph.D.; Stanley H. Johnson, Ph.D.; George E. Kane, M.A., P.E.; Celal N. Kostem, Ph.D.; Mark S. Lang, Ph.D.; Arthur I. Larky, Ph.D.; Robert A. Lucas, Ph.D.; William L. Luyben, Ph.D.; Michael R. Notis, Ph.D.; John B. Ochs, Ph.D.; Nicholas G. Odrey, Ph.D.; M. Tulga Ozsoy, Ph.D.; Alan W. Pense, Ph.D.; N. Duke Perreira, Ph.D.;Louis J. Plebani, Ph.D.; Richard Roberts, Ph.D.; Guruswami Sathyanarayanan, Ph.D.; William E. Schiesser, Ph.D.; Harvey G. Stenger, Jr., Ph.D.; S. Kenneth Tarby, Ph.D.; Theodore A. Terry, Ph.D., P.E.; David A. Thomas, Sc.D.; Marvin H. White, Ph.D.; John C. Wiginton, Ph.D.; John L. Wilson, Ph.D.; John D. Wood, Ph.D.; Emory W. Zimmers, Ph.D.

### *Center for Innovation Management Studies*

Drown Hall 35; 758-3427

Alden S. Bean, Ph.D., *director;* J. Richard Aronson, Ph.D.; Richard W. Barsness, Ph.D.; John W. Bonge, Ph.D.; Donald T. Campbell, Ph.D.; Steven L. Goldman, Ph.D.; John B. Guerard, Ph.D; Roy C. Herrenkohl, Ph.D.; Donald J. Hillman, Ph.D.; James B. Hobbs, D.B.A.; Raymond L. Horton, Ph.D.; Thomas J. Hyclak, Ph.D.; George E. Kane, M.S.; Michael g. Kolchin, D.B.A.; James A. Largay, Ph.D.; Benjamin Litt, Ph.D.; Bruce M. Smackey, Ph.D.; John C. Wiginton, Ph.D.

### *Center for International Studies*

215 Maginnes Hall #9; 758-4745

Z. J. Slouka, Ph.D., *director;* Karen Keim, Ph.D., study abroad coordinator; J. Richard Aronson, Ph.D.; Donald D. Barry, Ph.D.; Raymond Bell, Ed.D.; Alvin Cohen, Ph.D.; Stephen H. Cutcliffe, Ph.D.; Carey B. Joynt, Ph.D.; David W. Lewis, Ph.D.; Michael R. Notis, Ph.D.; Donald O.Rockwell, Ph.D.; Laurence J. Silberstein, Ph.D.; John C. Wiginton, Ph.D.; Raymond F. Wylie, Ph.D.

### *Center for Molecular Bioscience and Biotechnology*

111 Research Drive; 758-5426

Arthur E. Humphrey, Ph.D., director; Cinda S. Herndon-King, Ph.D., deputy director; John H. Abel, Jr., Ph.D., cell biology; isolation, purification, characterization, synthesis and utilization of gonadotropin receptors; Jack A. Alhadeff, Ph.D., biochemistry; purification and characterization of biomedically important enzymes, proteins and glycoproteins; Barry S.. Bean, Ph.D., biology; microbial behavior and metabolism; genetics; Michael Behe, Ph.D., biochemistry; biophysical chemistry of nucleic acid and chromatin structure; Jarrett L. Burton, Ph.D., reproductive cell biology; cryopreservation, chemotactic behavior; Marvin Charles, Ph.D., chemical engineering; scale-up and plant design of fermentation, enzyme and separation systems; G. Doyle Daves, Ph.D., organic chemistry; isolation, structure elucidation and synthesis of natural products with important biological properties; Natalie I. Foster, Ph.D., chemistry; use of NMR and enhancement agents for medical imaging and delineation of malignancies; Arthur E. Humphrey, Ph.D., chemical engineering, modelling, monitoring and control of fermentation and enzyme processes; James T. Hsu, Ph.D., chemical engineering; process technology for the separation and purification of biological molecules; Linda Lowe-Krentz, Ph.D., biochemistry and molecular biology; utilization of tissue culture of animal cells for the study of cell-cell interaction and communication; Michael Kutcha, Ph.D., genetics of plant-cell systems; Irwin J. Kugelman, Ph.D., anaerobic biological treatment processes, wastewater and waste treatment processes; John G. Nyby, Ph.D., hormones, nervous system and behavior; auditory and pheromonal communication; Janice A. Phillips, Ph.D., chemical engineering; kinetics of fermentation, cell culture and enzyme processes; enzyme and cell immobilization; monitoring and control of fermentation and separation systems; Steven L. Regen, Ph.D., organic chemistry; synthesis and characterization of novel polymerized esicles for potential use as drug carriers, model biomembranes and catalysts for organic syntheses; James E. Roberts, Ph.D., physical chemistry; use of solid-state NMR techniques to analyze structure and/or function

of solid materials including membrane proteins; Jeffrey A. Sands, Ph.D., biophysics; development and use of new gene-cloning systems for efficient production, processing and secretion of proteins; Keith J. Schray, Ph.D., organic chemistry; development of clinical assays including chemiluminescent and enzyme immunoassays; Arup K. Sengupta, Ph.D., wastewater management, waste treatment; Neal G. Simon, Ph.D., steroid receptor biology, neuroendocrinology; Vassie C. Ware, Ph.D., biology; study of molecular mechanisms regulating gene expression in eukaryotes.

## *Center for Social Research*

203 E. Packer Ave.; 758-3800

Roy C. Herrenkohl, Ph.D., *director;* Arthur E. King, Ph.D., assistant director; Donald T. Campbell, Ph.D.; Brenda P. Egolf, M.A., research scientist; John B. Gatewood, Ph.D.; Ellen C. Herrenkohl, Ph.D., research scientist; Patricia J. Horton, Ph.D., research scientist; Raymond L. Horton, D.B.A.; Diane T. Hyland, Ph.D.; Michael G. Kolchin, Ph.D.; Judith N. Lasker, Ph.D.; Vincent G. Munley, Ph.D.; Sandra L. Pipp, Ph.D.; Joan Z. Spade, Ph.D.; S. Lloyd Williams, Ph.D.

## *Center for the Application of Mathematics*

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## *Chemical Process Modeling and Control Research Center*

111 Research Dr.; 758-7781

Christos Georgakis, Ph.D., *center director;* William L. Luyben, Ph.D., *co-director;* Harvey G. Stenger, Ph.D., *associate director;* Hugo S. Caram, Ph.D.; John C. Chen, Ph.D.; Mohammed S. El-Aasser, Ph.D.; D.G. Harlow, Ph.D.; William R. Hencke, manager, liaison program; Arthur E. Humphrey, Ph.D.; Stanley H. Johnson, Ph.D.; Andrew Klein, Ph.D.; Janice A. Phillips, Ph.D.; Matthew J. Reilly, Ph.D.; David A. Sanchez, Ph.D.; William E. Schiesser, Ph.D.; Robert H. Storer, Ph.D.; John C. Wiginton, Ph.D.

## *Division of Bioengineering*

Eric P. Salathe, Ph.D., division *director;* mathematical modeling in circulatory system; John G. Michopoulos, Ph.D., high-voltage electrophotography applied to detect damage in bones and tissues; George C. M. Sih, Ph.D., material for artificial limbs, prosthetic apparatus; Ramamirtham Venkataraman, Ph.D., mathematical modeling

## *Division of Biological Chemistry and Biophysics*

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## *Emulsion Polymers Institute*

111 Research Drive; 758-3590

Mohamed S. El-Aasser, Ph.D., *co-director;* John W. Vanderhoff, Ph.D., *co-director;* Andrew Klein, Ph.D.; Frederick M. Fowkes, Ph.D.; Christos Georgakis, Ph.D.; Keith Schray, Ph.D.; Ph.D.; Fortunato J. Micale, Ph.D.; Cesar Silebi, Ph.D.; E. David Sudol, Ph.D.; Victoria Dimonie, Ph.D.; Eric S. Daniels, Ph.D.; Olga Shaffer.

## *Energy Research Center*

Packard Laboratory 19; 758-4090

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## *Engineering Research Center for Advanced Technology for Large Structural Systems (ATLSS)*

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## *Environmental Studies Center*

Chandler-Ullmann Hall; 758-3670

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## *Fritz Engineering Laboratory*

Fritz Engineering Laboratory 13; 758-3566

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## *Health Sciences Institute*

111 Research Drive; 758-3645

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## *Iacocca Institute*

111 Research Drive; 758-5452

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## *Institute for Metal Forming*

Whitaker Laboratory 5; 758-4234

Betzalel Avitzur, Ph.D., *director;* Ye T. Chou, Ph.D.; Samy Talbert, Ph.D., adjunct.

## *Institute for Robotics*

H.S. Mohler Laboratory #200; 758-4826

Nicholas G. Odry, Ph.D., *director;* Richard Roberts, Ph.D., associate director; Forbes T. Brown, Sc.D.; Bruce D. Fritchman, Ph.D.; Samuel L. Gulden, M.A.; Mikell P. Groover, Ph.D.; Donald J. Hillman, M.Litt.; Stanley H. Johnson, Ph.D.; Andrew J. Kasarda, Ph.D.; Keith A. Krenz, M.S., research engineer; Mark S. Lang, Ph.D.; Arthur I. Larky, Ph.D.; Robert A. Lucas, Ph.D.; John B. Ochs, Ph.D.; N. Duke Perreira, Ph.D.; Louis J. Plebani, Ph.D.; Herbert Rubenstein, Ph.D.; Theodore A. Terry, Ph.D.; Marvin H. White, Ph.D.; Emory W. Zimmers, Ph.D.

## *Institute for the Study of the High-Rise Habitat*

Fritz Engineering Laboratory 13; 758-3515

Nicholas Adams, Ph.D.; Lynn S. Beedle, Ph.D.; David C. Amidon, Jr., M.A.; George C. Driscoll, Ph.D.; James A. Hall, Ph.D.; Francis A. Harvey, Ed.D.; Roy C. Herrenkohl, Ph.D.; Donald J. Hillman, Ph.D.; Ti Huang, Ph.D.; Celal N. Kostem, Ph.D.; Irwin J. Kugelman, Sc.D.; Le-Wu Lu, Ph.D.; Peter Mueller, Dr.Sc.tech; Warren A. Pillsbury, Ph.D.; Roger D. Simon, Ph.D.; Steven Thade, D.B.A.; Robert C. Williamson, Ph.D.; John L. Wilson, Ph.D.; Ivan Zaknic, M.A.

## *Institute of Fracture and Solid Mechanics*

Packard Laboratory 19; 758-4130

George C.M. Sih, Ph.D., *director;* Fazil Erdogan, Ph.D.; Ronald J. Hartranft, Ph.D.; John G. Michopoulos, Ph.D.; Robert A. Lucas, Ph.D.; Richard Roberts, Ph.D.; Robert G. Sarubbi, Ph.D.; Dean P. Updike, Ph.D.; Robert P. Wei, Ph.D.

## *Institute of Thermo-Fluid Engineering and Science*

111 Research Drive; 758-4091

John C. Chen, Ph.D., *director;* Philip A. Blythe, Ph.D.; Forbes T. Brown, Ph.D.; Hugo Caram, Ph.D.; Curtis W. Clump, Ph.D.; Christos Georgakis, Ph.D.; Edward K. Levy, Ph.D.; William L. Luyben, Ph.D.; Alister K. Macpherson, Ph.D.; Sudhakar Neti, Ph.D.; Jerzy A. Owczarek, Ph.D.; Donald O. Rockwell, Ph.D.; Robert G. Sarubbi, Ph.D.; William E. Schiesser, Ph.D.; Cesar A. Silebi, Ph.D.; Charles R. Smith, Ph.D.; Wesley R. Smith, Ph.D.; Frank P. Stein, Ph.D.; Kyra Stephanoff, Ph.D.; Kemal Tuzla, Ph.D.; Ramamirtham Venkataraman, Ph.D.; Leonard A. Wenzel, Ph.D.

## *Lawrence Henry Gipson Institute for Eighteenth-Century Studies*

Maginnes Hall 9; 758-3366

Jan Fergus, Ph.D., *co-director;* James S. Saeger, Ph.D., *co-director;* Michael D. Baylor, Ph.D.; Stephen H. Cutcliffe, Ph.D.; Edward J. Gallagher, Ph.D.; James D. Gunton, Ph.D.; John W. Hunt, Ph.D.; Lawrence H. Leder, Ph.D.; Richard K. Matthews, Ph.D.; D. Alexander Waldenrath, Ph.D.

## *Lehigh Valley Center for Jewish Studies*

321 Maginnes Hall 9; 758-4869

Laurence J. Silberstein, Ph.D., *director;* Myra Rosenhaus, Ph.D., program administrator; Robert Cohn, Ph.D., (Lafayette College); Alan Mittleman, Ph.D., (Muhlenberg College); Chava Weissler, Ph.D., (Lehigh University); Elie Rekhess, Ph.D., visiting professor. Associated faculty: David C. Amidon, Jr., M.A., Alice Eckhardt, M.A., professor emerita; Elizabeth N. Fifer, Ph.D.; Hubert L. Flesher, M.A.; Steven L. Goldman, Ph.D.; Harriet L. Parmet, M.Sc.Ed.; Oles M. Smolansky, Ph.D.

## *Martindale Center for the Study of Private Enterprise*

Drown Hall 35; 758-4711

J. Richard Aronson, Ph.D., *director;* Robert J. Thornton, Ph.D., associate director; Kenneth P. Sinclair, Ph.D., associate director; Thomas J. Hyclak, Ph.D., associate director; Frank R. Gunter, Ph.D., head advisor to undergraduate students; John W. Paul, Ph.D., head advisor to MBA students; Arthur E. King, Ph.D., Canadian Studies Program director; Richard W. Barsness, Ph.D., dean; Carl R. Beidleman, Ph.D.; Michael L. Davis, Ph.D.; James

M. Maskulka, Ph.D..; John R. McNamara, Ph.D.; Vincent G. Munley, Ph.D.; Jon T. Innes, Ph.D.; Alvin Cohen, Ph.D.; James A. Hall, Ph.D.

## *Materials Research Center*

Whitaker Laboratory 5; 758-3850

Donald M. Smyth, Ph.D., *director;* Gary A. Miller, Sc.D., *associate director* and *director,* materials liaison program; Clifford C. Hanninen, Ph.D., associate director, materials liaison program; Sidney R. Butler, Ph.D., ceramics research laboratory; Helen M. Chan, Ph.D., ceramics research laboratory; Y. T. Chou, ceramics research laboratory; Guy M. Connelly, M.S., mechanical behavior laboratory; Gary G. DeLeo, ceramics research laboratory; Joseph I. Goldstein, Sc.D., electron optical laboratory; Martin P. Harmer, Ph.D., director, ceramics research laboratory; Richard W. Hertzberg, Ph.D., *director,* mechanical behavior laboratory; Himanshu Jain, Ph.D., ceramics research laboratory; Charles E. Lyman, Ph.D., electron optical laboratory; Michael R. Notis, Ph.D., ceramics research laboratory; Leslie H. Sperling, Ph.D., director, polymer laboratory; David A. Thomas,Sc.D., polymer laboratory; Jean Toulouse, ceramics research laboratory; David B. Williams, Ph.D., *director,* electron optical laboratory

## *Musser Center for Entrepreneurship*

301 Broadway; 758-3980

John W. Bonge, Ph.D., *director;* Small Business Development Center: John W. Bonge, Ph.D., *director; John E. Stevens, Ph.D., associate director; Larry A. Strain, M.B.A., program administrator; B. Kathryn Frazier, M.B.A., associate administrator; Mehdi Hojjat, Ph.D., coordinator of international trade development program; Patrick F. McCarthy, coordinator of government marketing assistance program; Dawn L. Steimel, coordinator of financing assistance program.*

## *Rauch Center for Business Communications*

Drown Hall 35; 758-4863

Richard W. Barsness, Ph.D., *director;* June A. West, M.Ed., *associate director.*

## *Sherman Fairchild Center for Solid-State Studies*

Sherman Fairchild Laboratory 161; 758-3950

Ralph J. Jaccodine, Ph.D., *director,* and Sherman Fairchild Professor of Solid-State Studies; Sidney R. Butler, Ph.D.; Richard D. Decker, Ph.D.; Gary G. DeLeo, Ph.D.; Frank J. Feigl, Ph.D.; W. Beall Fowler, Ph.D.; Miltiadis Hatalis, Ph.D.; Karl H. Norian, Ph.D.; Wesley R. Smith, Ph.D.; Donald M. Smyth, Ph.D.; Jean Toulouse, Ph.D.; Marvin H. White, Ph.D., Sherman Fairchild Professor of Solid-State Studies; George D. Watkins, Ph.D., Sherman Fairchild Professor of Solid-State Studies; Donald R. Young, Ph.D.

## *Small Business Development Center*

(see Musser Center for Entrepreneurship)

## *Institute of Marine Studies*

William Hall, 31; 758-3694

Murray Itzkowitz, Ph.D., *director*; behavioral ecology of fishes and shore birds; Charles Wahle, Ph.D., Stone Harbor Marine Laboratory, benthic ecology; Bobb Carson, Ph.D., geological oceanography; Elizabeth Chornesky, Ph.D., invertebrate benthic ecology; John B. Gatewood, Ph.D., anthropology of marine commercial fishermen and anglers; Bruce R. Hargreaves, Ph.D., environmental physiology; Sidney S. Herman, Ph.D., biological oceanography; Gerard P. Lennon, Ph.D., ground water hydrology and coastal engineering; Sibel Pamuku, Ph.D., environmental geotechnology; Paul Samallow, Ph.D., population genetics; Robert Sorensen, Ph.D., coastal structures, shore-structures interactions; Richard N. Weisman, Ph.D. surface hydrology and coastal engineering

## *Science, Technology and Society Program and Technology Studies Resource Center*

Maginnes Hall 9; 758-3550

Stephen H. Cutcliffe, *director,* Science, Technology and Society Program and Technology Studies Resource Center; R. Nicholas Adams, art and architecture; Rosemarie Arbur, English; Nicholas Balabkins, economics; Robert F. Barnes, philosophy and computer science and electrical engineering; Alden S. Bean, management and marketing; Gordon Bearn, philosophy; Lynn S. Beedle, civil engineering; Thomas O. Blank, social relations; Patricia T. Bradt, research scientist; Arthur L. Brody, psychology; Donald T. Campbell, social relations and psychology; Gail Cooper, history; Jack A. DeBellis, English; Robin Dillon, philosophy; John H. Ellis, history; Edward B. Evenson, geological sciences; Hubert L. Flesher, religion studies; Barbara B. Frankel, social relations; Sharon M. Friedman, journalism; Edward J. Gallagher, English; Norman J. Girardot, religion studies; Steven L. Goldman, philosophy and history; Mikell P. Groover, industrial engineering; John E. Hare, philosophy; Robert Harson, English; Francis A. Harvey, education; Ned D. Heindel, chemistry; Roy C. Herrenkohl, social relations; R. Wayne Kraft, materials science and engineering; Irwin J. Kugelman, civil engineering; Judith N. Lasker, social relations; Benjamin Litt, management and marketing; John R. McNamara, economics; Norman P. Melchert, philosophy; Jeffrey Milet, speech and theater; Roger N. Nagel, computer science and electrical engineering; Michael R. Notis, materials science and engineering; Alan W. Pense, materials science and engineering; Tom F. Peters, art and architecture; Michael Raposa, religion studies; Richard J. Redd, art and architecture; Christine M. Roysdon, Linderman Library; Paul F. Salerni, music; William E. Schiesser, chemical engineering; Charles B. Sclar, geological sciences; George K. Shortess, psychology; Roger D. Simon, history; Zdenek J. Slouka, international relations; Bruce M. Smackey, management and marketing; John K. Smith, history; LeRoy J. Tuscher, education; Ricardo Viera, art and architecture; Albert H. Wurth, government; Raymond F. Wylie, international relations.

## *Zettlemoyer Center for Surface Studies*

Sinclair Laboratory 7; 758-3571

Gary W. Simmons, Ph.D., *director;* Robert P. Eischens, adjunct faculty; Frederick M. Fowkes, Ph.D., professor emeritus of chemistry; Leonard E. Klebanoff, Ph.D., assistant professor of chemistry and director, surface magnetism laboratory; Kamil Klier, Ph.D., professor of chemistry and director, catalysis laboratory; John W. Larsen, Ph.D., professor of organic chemistry; Henry Leidheiser, Jr., Ph.D., professor of chemistry and *director,* corrosion laboratory; Charles E. Lyman, Ph.D., associate professor of metallurgy and materials engineering; Fortunato J. Micale, Ph.D., professor of chemistry and *director,* colloid laboratory; Steven L. Regen, Ph.D., professor of organic and polymer chemistry; Gary W. Simmons, Ph.D., professor of chemistry and *director,* surface analysis laboratory; Harvey G. Stenger,Jr., assistant professor of chemical engineering; Israel Wachs, Ph.D., associate professor of chemical engineering and director, vibrational spectroscopy laboratory; Robert P. Wei, Ph.D., professor of mechanical engineering and mechanics and *director,* environment-sensitive fracture laboratory; Albert C. Zettlemoyer, university distinguished professor and provost emeritus; Jerzy Datka, Ph.D.; Richard D. Granata, Ph.D.; Richard G. Herman, Ph.D.; S-H.; Diego Valenzuela, Ph.D.

# Visiting Committees

A university both serves and advances society. It accomplishes this through various highly specialized academic, research, and service divisions. To achieve a perspective of societal needs and goals and the direction and role to be played by the university, the university and society must develop links of communication. At Lehigh University, one means of forging such links is through involvement of specialists outside the university with university personnel.

In addition, it is essential to the progress of the university that the direction and quality of each unit be maintained. The regular visit of a group of highly qualified individuals from the outside provides both a stimulus for self-appraisal by a given department or division, and an objective view by an outside group of the work of that unit.

Therefore, to forge these communication links and to maintain continuous interaction of the units of the university with the off-campus world, the Lehigh board of trustees on June 4, 1965, established visiting committees. A listing of committees follows.

## *Art and Architecture*

S. Murray Rust, Jr., *chairperson*, Orleans, Mass. and Naples, Fla., retired chairman, Rust Engineering Co.

Murray H. Goodman, West Palm Beach, Fla., chairman of the board, The Goodman Company

Andrew MacNair, New York City, N.Y., associate professor, Parsons School of Design.

## *Intercollegiate Athletics*

C. Keith Rust, *chairperson*, Bethlehem, Pa., president, Roland and Roland, Inc.

Curtis F. Bayer, honorary member, Chagrin Falls, Ohio, retired vice president, Erie Lackawanna Railroad

Edward N. Cahn, Allentown, Pa., U.S. district judge

Samuel W. Croll, Jr., Orleans, Mass., and Naples, Fla., retired president, Croll-Reynolds Co., Inc.

Samuel C. Howell, Princeton, N.J., associate director of athletics, Princeton University

Nancy Barrett Kreider, Cincinnati, Ohio, alumni representative

## *Biology*

Frank C. Rabold, *chairperson*, Saylorsburg, Pa., retired general manager of corporate services, Bethlehem Steel Corp.

Bert DelVillano, Malvern, Pa., vice president of marketing and sales, Centocor

Dean F. Dimick, M.D., Allentown, Pa., vice president of academic affairs, Health East, Inc., Lehigh Valley Hospital Center.

Stephanie Olexa, Allentown, Pa., section manager, research and development, Air Products and Chemicals, Inc.

Stanley Person, State College, Pa., emeritus professor of molecular cell biology, Pennsylvania State University.

Nalin Unakar, Rochester, N.Y., chairman, department of biology, Oakland University

## *College of Business and Economics*

Eugene Mercy, Jr., *chairperson*, New York City, partner, Goldman Sachs & Co.

Austin O. Furst, chairman of the board, Vestron Video, Inc.

Robert B. Gill, Dallas, Texas, vice chairman, J.C. Penney Co., Inc.

William L. Gladstone, New York City, chairman and chief executive officer, Arthur Young & Co.

Murray H. Goodman, West Palm Beach, Fla., chairman of the board, The Goodman Company.

James N. Land, Jr., Short Hills, N.J., financial consultant

Joseph R. Perella, New York City, managing director, The First Boston Corp.

William P. Pierskalla, deputy dean for academic affairs, The Wharton School, University of Pennsylvania

Paul J. Uselding, Cedar Falls, Iowa, dean, school of business, University of Northern Iowa

Frank E. Walsh, Jr., Morristown, N.J., vice chairman, Wesray Corp.

## *Chemical Engineering*

Dexter F. Baker, *chairperson* ,Allentown, Pa., president, Air Products and Chemicals, Inc.

P. L. Thibaut Brian, Allentown, Pa., vice president of engineering, Air Products and Chemicals Inc.

David S. Hollingsworth, Wilmington, Del., chairman and chief executive officer, Hercules, Inc.

Roger A. Schmitz, Notre Dame, Ind., vice president and associate provost, University of Notre Dame

Paul V. Tebo, Wilmington, Del., technical director of research and development division, Polymer Products Department, E.I. du Pont de Nemours & Co.

## *Chemistry*

William B. Eagleson, *chairperson*, Malvern, Pa., retired chairman emeritus, Mellon Bank (East)

## *Civil Engineering and Fritz Engineering Laboratory*

Donald B. Stabler, *chairperson*, Harrisburg, Pa., president and chairman of the board, Stabler Companies, Inc.

Richard S. Engelbrecht, Urbana, Ill., professor of civil engineering, University of Illinois

Geerhardt Haaijer, Chicago, Ill., vice president and director of engineering, American Institute of Steel Construction

Arnold Jones, Cary, N.C., former vice president of operations, real estate and construction division, IBM Corp.

Joseph S. Ward, Montclair,N.J., consulting geotechnical engineer

## *Classics*

James B. Swenson, *chairperson*, Wellesley, Mass., partner, Price Waterhouse

Walter S. Holmes Jr., Ocean City, N.J., and Delray Beach, Fla., retired chairman of the board, CIT Financial Corp.

Eleanor Leach, Bloomington, Ind., professor of classical studies, Indiana University

William C. Scott, Hanover, N.H., professor of classics, Dartmouth College

## *Computer Science and Electrical Engineering*

John Diebold, *chairperson*, New York City, president and chairman of the board, The Diebold Group, Inc.

Joel S. Birnbaum, Cupertino, Calif., vice president and general

manager, Information Architecture Group, Hewlett Packard

Lester Eastman, Ithaca, N.Y., professor of electrical engineering, Cornell University

George I. Haddad, Ann Arbor, Mich., chairman and professor of electrical engineering, University of Michigan

Dennis Hill, Allentown, Pa., manufacturing vice president MOS, AT&T

## *Computing and Communications*

Robert Gallagher, Troy, N.Y., director of information technology services, Rensselaer Polytechnic Institute

Bruce Gilchrist, New York City, director, computing activities, Columbia University

Michael J. Levine, Pittsburgh, Pa., scientific director, Pittsburgh Supercomputing Center

Glenn Ricart, College Park, Md., director, computer science center, University of Maryland

Albert L. Siegel, Columbus, Ohio, manager of computing and telecommunications, Battelle Memorial Institute

## *College of Education*

Joseph M. Workman, *chairperson*, Bethlehem, Pa., manager, business planning, Bethlehem Steel Corp.

Sylvia Charp, Upper Darby,Pa., editor-in-chief, TECHNOLOGICAL HORIZONS IN EDUCATION

Peter J. Fioretti, Hoboken, N.J., partner, Waterfront Invest

Edwin L. Herr, University Park, Pa., head and professor of counseling and educational psychology, Pennsylvania State University

Sylvia Rosenfield, Philadelphia, Pa., professor, school of psychology program, Temple University

## *Energy Research Center*

Ronald R. Hoffman, *chairperson*, Pittsburgh, Pa., group vice president, Alcoa packagings systems, Aluminum Company of America

Peter L. Auer, Ithaca, N.Y., professor of mechanical and aerospace engineering, Cornell University

John Bachofer, Reading, Pa., vice president, Generation, Metropolitan Edison Co.

Domenic A. Canonico, Chattanooga, Tenn., director, metallurgy and materials laboratory, Combustion Engineering Inc.

David M. Eissenberg, Oak Ridge, Tenn., program manager, Engineering Technology Division, Oak Ridge National Laboratory

## *English*

William L. Clayton, *chairperson*, New York City, executive vice president and director, E.F. Hutton & Co.

Donna Gerstenberger, Seattle, Wash., professor of English, University of Washington

John Kuehl, New York City, professor of English, New York University

Donald Ross, Jr., Minneapolis, Minn., professor of English, University of Minnesota

## *Environmental Studies Center*

Robert H. Riley, Jr., *chairperson*, Towson, Md., retired director, Black & Decker Manufacturing Co.

Anthony F. Gaudy, Jr., Newark, Del., H. Rodney Sharp Professor of Civil Engineering, University of Delaware

Alonzo W. Lawrence, Pittsburgh, Pa., vice president for science and technology, Koppers Co. Inc.

## *Geological Sciences*

Philip J. Berg, *chairperson*, Sewickley, Pa., retired executive vice president, Dravo Corp.

Shelton S. Alexander, University Park, Pa., chairman and professor of geophysics, Pennsylvania State University

Stephen P. Morzenti, Glenrock, Wyo., project manager, Everest Mineral Corp.

John T. Palmer, Shreveport, La., president, Palmer Petroleum, Inc.

George W. Roland, Labrobe, Pa., managing director, Kennametal, Ltd.

Leon T. Silver, Pasadena, Calif., professor of geology, California Institute of Technology

## *Government*

Philip R. Peller, *chairperson*, Glen Head, N.Y., partner, Arthur Andersen & Co.

Lon S. Babby, Washington, D.C., Williams and Connolly

Trond Gilberg, University Park, Pa., professor and chairperson, department of political science, Pennsylvania State University

Marion R. Just, Wellesley, Mass., chairperson and professor of political science, Wellesley College

## *History*

Frank C. Rabold, *chairperson*, Saylorsburg, Pa., retired general manager of corporate services, Bethlehem Steel Corp.; president, Unidel Corp.

Charles D. Ameringer, University Park, Pa., professor of history, Pennsylvania State University

Philip Cash, Boston, Mass., chairman and professor of history, Emmanuel College

Daniel S. Hirshfield, Westfield, N.J., president, Hirshfield and Associates

Alice Kessler-Harris, Hempstead, N.Y., professor of history, Hofstra University

Dominick A. Lockwood, Easton, Pa., attorney-at-law

Orest Ranum, Baltimore, Md., professor of history, Johns Hopkins University

Merrit Roe Smith, Cambridge, Mass., professor of history, Massachusetts Institute of Technology

## *Industrial Engineering*

William O. Fleckenstein, *chairperson*, retired vice president, Bell Communications Research.

L. Jack Bradt, Easton, Pa., chairman, The SI Handling Systems, Inc.

Michael M. Danchak, Hartford, Conn., dean, School of Engineering and Science, The Hartford Graduate Center

Thomas L. Kelly, Jr., Shelton, Conn., chief executive officer, TIE/Communications, Inc.

Patterson H. Krisher, New York City, national director of

management services and partner, Arthur Young & Co.

George T. Rehfeldt, Cincinnati, Ohio, group vice president, Industrial Specialty Products, Cincinnati Milacron, Inc.

John A. White, Atlanta, Ga., professor of industrial engineering and director, Material Handling Research Center, Georgia Institute of Technology

## *International Relations*

James M. Bridgman, *chairperson*, New Canaan, Conn., retired program manager, employee relations for Far East, IBM World Trade/Far East; consultant, IBM Corp.

Samuel Efron, Washington, D.C., senior partner, Arent, Fox, Kintner, Plotkin & Kahn

William C. Hittinger, Princeton, N.J., retired executive vice president, research and engineering, RCA Corp.

Roger E. Kanet, Urbana, Ill., professor and head, department of political science, University of Illinois at Urbana-Champaign

Gerard J. Mangone, Newark, Del., H. Rodney Sharp Professor of International Law and Organization and director, Center for the Study of Marine Policy, University of Delaware

Donald J. Puchala, Columbia, S.C., professor of international relations and director, Center for International Studies, University of South Carolina

## *Journalism*

Kirk P. Pendleton, *chairperson*, Bryn Athyn, Pa., president, Cairnwood, Inc.

Eileen Canzian, Baltimore,Md., reporter, BALTIMORE SUN

Kenneth Goldstein, New York City, professor, School of Journalism, Columbia University

Douglas Ann Newson, Fort Worth, Texas, professor of journalism, Texas Christian University

Robert Teufel, Jr., Emmaus, Pa., president, Rodale Press, Inc.

Robert M. Walters, Washington, D.C., syndicated columnist

## *University Libraries*

William E. Zeiter, Esq., *chairperson*, Philadelphia, Pa., partner, Morgan, Lewis & Bockius

Patricia Battin, Washington, D.C., president, National Preservation Committee, Council of Library Resources

Guy Garrison, Philadelphia, Pa., professor, College of Information Studies, Drexel University

Jay K. Lucker, Cambridge, Mass., director of libraries, Massachusetts Institute of Technology

David Stam, Syracuse, N.Y., university librarian, Syracuse University

## *Department of Materials Science and Engineering, and Materials Research Center*

Frederick C. Langenberg, *chairperson*, Oak Brook, Ill., chairman and chief executive officer, Interlake

Donald R. Paul, Austin, Texas, T. Brockett, professor of chemical engineering, The University of Texas-Austin

James R. Rice, Cambridge, Mass., professor of engineering science and geophysics, Harvard University

Ellis D. Verink, Jr., Gainesville, Fla., professor of materials science and engineering, University of Florida

## *Department of Mathematics*

William C. Hittinger, *chairperson*, Princeton, N.J., retired executive vice president, research and engineering, RCA Corp.

Julian Cole, Troy, N.Y., professor of mathematics, Rensselaer Polytechnic Institute

Samuel Gitler, Rochester, N.Y., professor and chairman, department of mathematics, University of Rochester.

Andrew M. Gleason, Cambridge, Mass., professor of mathematics, Harvard University

Ronald L. Graham, Murray Hill, N.J., director, Mathematical Sciences Research Center, Bell Laboratories

John W. Tukey, Princeton, N.J., professor, Princeton University

## *Mechanical Engineering and Mechanics*

Richard M. Smith, *chairperson*, Macungie, Pa., retired vice chairman, Bethlehem Steel Corp.

Donald P. Ames, St. Louis, Mo., staff vice president, McDonnell Douglas Research Laboratories

Bernard Budiansky, Cambridge, Mass., Gordon McKay Professor of Mechanical Engineering, Harvard University

William M. Kays, Stanford, Calif., professor of mechanical engineering, Stanford University

Zdenek J. Lansky, Solon, Ohio, vice president, Parker Hannifin Corp.

David H. Mitchell, Norwalk, Conn., group director, supply management, Information Systems Group, IBM Corp.

W. M. Phillips, West Lafayette, Ind., head, school of mechanical engineering, Purdue University

Donald Stewart, Canton, Ohio, chairman of the board and chief executive officer, Hercules Engines, Inc.,

## *Modern Foreign Languages and Literature*

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Michael J. Curschmann, Princeton, N.J., professor of German, Princeton University

Howard M. Fraser, Williamsburg, Va., professor of modern language, College of William and Mary

Willard F. King, Bryn Mawr, Pa., professor of Spanish, Bryn Mawr College

Ernest A. Scatton, Albany N.Y., director, program in linguistics, State University of New York at Albany

## *Center for Molecular Bioscience and Biotechnology*

Theodore L. Diamond, *chairperson*, New York City, president, T.L. Diamond & Co., Inc.

Bert DelVillano, Malvern, Pa., vice president of marketing and sales, Centocor

Thomas M. Devlin, Philadelphia, Pa., professor and chairman, department of biological chemistry, Hahnemann University School of Medicine

Renato Fuchs, Malvern, Pa., vice president for development, Centocor

Seemon Pines, Rahway, N.J., vice president, process research &

development, Merck & Company, Inc.

Richard K. Quisenberry, Wilmington, Del., director, biotechnology research division, E.I. du Pont de Nemours & Co., Inc.

Morton K. Schwartz, New York City, chairman and professor of clinical chemistry, Memorial Sloan-Kettering Cancer Center

Daniel I-C. Wang, Cambridge, Mass., director of bioprocessing engineering research center, Massachusetts Institute of Technology

## *Music*

Dexter Baker, *chairperson*Allentown, Pa., president and chief executive officer, Air Products and Chemicals Inc.

Joseph Flummerfelt, Princeton, N.J., director of choral activities, Westminster Choir College

Earl Kim, Cambridge, Mass., James Diston Professor of Music, Harvard University

Mildred Parker, Philadelphia, Pa., professor of musicology, Temple University

## *Philosophy*

Augustus A. Riemondy, *chairperson*, Hershey, Pa., retired brigadier general, U.S. Air Force; retired assistant to the president, Hershey Foods Corp.

Annette Baier, Pittsburgh, Pa., professor of philosophy, University of Pittsburgh

Daniel C. Dennett, Medford, Mass., professor of philosophy, Tufts University

Gilbert Harman, Princeton, N.J., professor of philosophy, Princeton University

Hugh M. Lacey, Swarthmore, Pa., professor of philosophy, Swarthmore College

Dudley Shapere, Winston-Salem, N.C., professor of philosophy, Wake Forest University

## *Physics*

Ronald R. Hoffman, *chairperson*, Pittsburgh, Pa., vice president, Flat-rolled Products Division, Aluminum Company of America

Robert A. Gross, New York City, Dean and Percy K. and Vida L.W. Hudson Professor of Applied Physics, Columbia University

Charles V. Shank, Holmdel, N.J., director of electronics research laboratory, AT&T Bell Laboratories

## *Psychology*

Augustus A. Riemondy, *chairperson*, Hershey, Pa., retired brigadier general, U.S. Air Force; retired assistant to the president, Hershey Foods Corp.

Joseph H. Grosslight, Tallahassee, Fla., professor and chairman, department of psychology, Florida State University

William Kessen, New Haven, Conn., Eugene Higgins Professor of Psychology and professor of pediatrics, Yale University

Marsha B. Marson, Charlestown, Mass., manufacturing specialist, The New Can Co., Inc.

## *Religion Studies*

The Very Rev. Daniel Gambet, OSFS, *chairperson*, Center Valley, Pa., president, Allentown College of St. Francis de Sales

Kalman P. Bland, Durham, N.C., chairman and professor of religion, Duke University

Wendy Doniger O'Flaherty, Chicago, Ill., professor of religions, University of Chicago

Marilyn Waldman, Columbus, Ohio, professor of history, Ohio State University

## *Sherman Fairchild Center for Solid-State Studies*

William O. Fleckenstein, *chairperson*, Bethlehem, Pa., retired vice president, Bell Communications Research

Lionel Kimerling, Murray Hill, N.J., head, materials physics research, AT&T Bell Laboratories

Denish Mehta, Allentown, Pa., vice president of MOS product management & marketing, AT&T Microelectronics

T. D. Ramachandran, North Billerica, Mass., president, M/A-COM Advanced Semiconductor Operations

James J. Tietjen, Princeton, N.J., president and chief operating officer, David Sarnoff Research Center

## *Social Relations*

Stanley M. Richman, *chairperson*, Millburn, N.J., vice president, Lightning Electric Co.

Walter L. Wallace, Princeton, N.J., professor of sociology, Princeton University

## *Center for Social Research*

Milton H. Grannatt, Jr., *chairperson*, West Trenton, N.J., chairman, Fell and Moon Co.

William A. Morrill, Princeton, N.J., president, Mathtech, Inc.

Henry McIlvaine Parsons, Alexandria, Va., senior staff scientist, Essex Corp.

James B. Swenson, Wellesley, Mass., partner, Price Waterhouse

Stewart Wolf,M.D., Bangor, Pa., director, Totts Gap Medical Laboratory

## *Department of Theatre*

Lucille Bunin Askin, honorary member, Scarsdale, N.Y., art lecturer

Arthur W. Bloom, Los Angeles, Calif., dean, school of fine arts, Loyola Marymount University

William T. Burgin, Wayne, Pa., professional actor

George C. Izenour, Stony Creek, Conn., professor emeritus of theater and technology

## *Student Life*

Ronald H. Vaughn, *chairperson*, Doylestown, Pa., president, Neapco, Inc.

Ernest Ern, Charlottesville, Va., vice president for student affairs, University of Virginia

Thomas E. Hirsch III, Washington, D.C., attorney, Chadburne and Parke

Stanley M. Richman, Millburn, N.J., vice president, Lightning Electric Co.

Arthur Sandeen, Gainesville, Fla., vice president for student affairs and professor of educational administration, University of Florida

### *Zettlemoyer Center for Surface Studies*

Brian Rushton, *chairperson*, Allentown, Pa., vice president, research and development, Air Products and Chemicals, Inc.

Michael Boudart, Stanford,Calif., William J. Keck Professor of chemical engineering, Stanford University

Donald P. Seraphim, Endicott, N.Y., materials engineering manager, IBM Corp.

# Honorary Degree Recipients

Lehigh University awarded honorary degrees to the following individuals during the past year.

## *Founder's Day, 1988*

**Doctor of Humane Letters**
Paul Varley, chairman of the department of East Asian languages and cultures at Columbia University, is considered one of America's foremost scholars on the culture and traditions of Japan. He has written six books on Japan, including 'Japanese Culture,' which is widely used as a college textbook. Varley, who graduated from Lehigh in 1952 with a bachelor's of science degree, became interested in Japan during a tour of duty there with the U.S. Army. He earned his M.A. and Ph.D. from Columbia.

**Doctor of Science**
William Schuler Pierce, M.D., principal developer of the Pennsylvania State University artificial heart, holds five U.S. patents and one Greek patent on heart-related inventions, including the cardiac valve and blood pump. As professor of surgery at Penn State's medical school in Hershey, Pa., he leads the school's mechanical-heart implant team and has performed more than 1,000 bypass operations. Dr. Pierce graduated from Lehigh in 1958 with a bachelor's degree in chemical engineering. He later graduated from the University of Pennsylvania Medical School.

## *Commencement, 1988*

**Doctor of Engineering**
Terry J. Hart was one of five U.S. astronauts who commandeered the successful flight of the Space Shuttle launched from Kennedy Space Center in April 1984. Hart, who earned a bachelor's of science degree in mechanical engineering from Lehigh in 1968, was responsible for rendezvous navigation and targeting, and remote manipulator and camera operations. Hart, a Lt. Col. in the Air Force, is project manager for the design of secure data processing systems for government applications with AT&T's Bell Labs. He holds master's degrees from Rutgers University and M.I.T. and has received two patents..

**Doctor of Law**
Donald J. Trump, president of the Trump Organization, is well-known for real-estate developments that have changed the skylines of New York City and Atlantic City, N.J. His Trump Tower, a 68-story, $200-million skyscraper, has become a New York landmark. His other New York developments include the Trump Plaza, a luxury cooperative, and the Grand Hyatt Hotel, a 1,500-room facility connected to the city's Grand Central Terminal. Trump is a graduate of the University of Pennsylvania's Wharton School of Finance.

**Doctor of Science**
Rosalym S. Yalow, winner of the 1977 Nobel Prize in medicine, is considered one of the founders of nuclear medicine. As a senior medical investigator at the Bronx V.A. Hospital in New York City, Dr. Yalow helped develop and popularize the radioimmunoassay. The technique is widely used to measure minute amounts of hormones, enzymes and other substances in the blood. It was credited by the Nobel Committee with 'bringing about a revolution in biological and medical research.' Dr. Yalow received her bachelor's degree in physics and chemistry from Hunter College in New York City and her master's and doctorate degrees in physics from the University of Illinois in Urbana.

**Doctor of Humane Letters**
Robert McAfee Brown, professor emeritus of religious studies at Pacific School of Religion in Berkeley, Calif., has been nationally active in civil rights and ecumenical movements since the 1960s. In 1961, he was arrested and jailed for trying to integrate the Tallahassee, Fla., Airport. During the Vietnam War, Brown advocated draft resistance and took part in demonstrations. Brown has written a dozen books on Christian theology and served as Protestant observer for North America at the first and second Vatican Councils. He holds degrees from Amherst College, Union Theological Seminary and Columbia University.

**Doctor of Law**
Murray H. Goodman is a Lehigh trustee and chairman of The Goodman Co., a commercial real-estate development firm in West Palm Beach, Fla. has made major gifts to help Lehigh develop its athletic and academic facilities. Goodman, who received a bachelor's of science degree in business administration from Lehigh in 1948, has made major gifts to his alma mater. He provided $2.5 million to develop and endow the university's 550-acre athletic complex in the Saucon Valley, now called the Murray H. Goodman Campus. He also donated $5 million to develop the Murray H. Goodman Center for Real Estate Studies and the Goodman Stadium. Goodman is a trustee of the Allentown Art Museum and the Eye Research Institute of Boston.

# How to Reach Bethlehem

Those who plan to visit Lehigh University can reach Bethlehem, Pa., by private car or commercial carrier. The university is located approximately ninety miles from New York City and sixty miles from Philadelphia. The Allentown-Bethlehem-Easton Airport, just ten minutes away by cab or airport limousine, is served by a number of national airlines.

Construction of the final segment of the I-78 interstate highway system will bring the route near Lehigh's Mountaintop and Murray H. Goodman campuses.

The following information may be of assistance to those planning to visit the campus.

**By plane.** Allentown-Bethlehem-Easton International Airport is served by United, Northwest, Eastern and U.S.Air airlines.

**By bus.** Trans Bridge Lines offers daily service to New York City and Newark International Airport. Carl R. Bieber Tourways offers regular service to and from Philadelphia. Greyhound also provides service for Bethlehem.

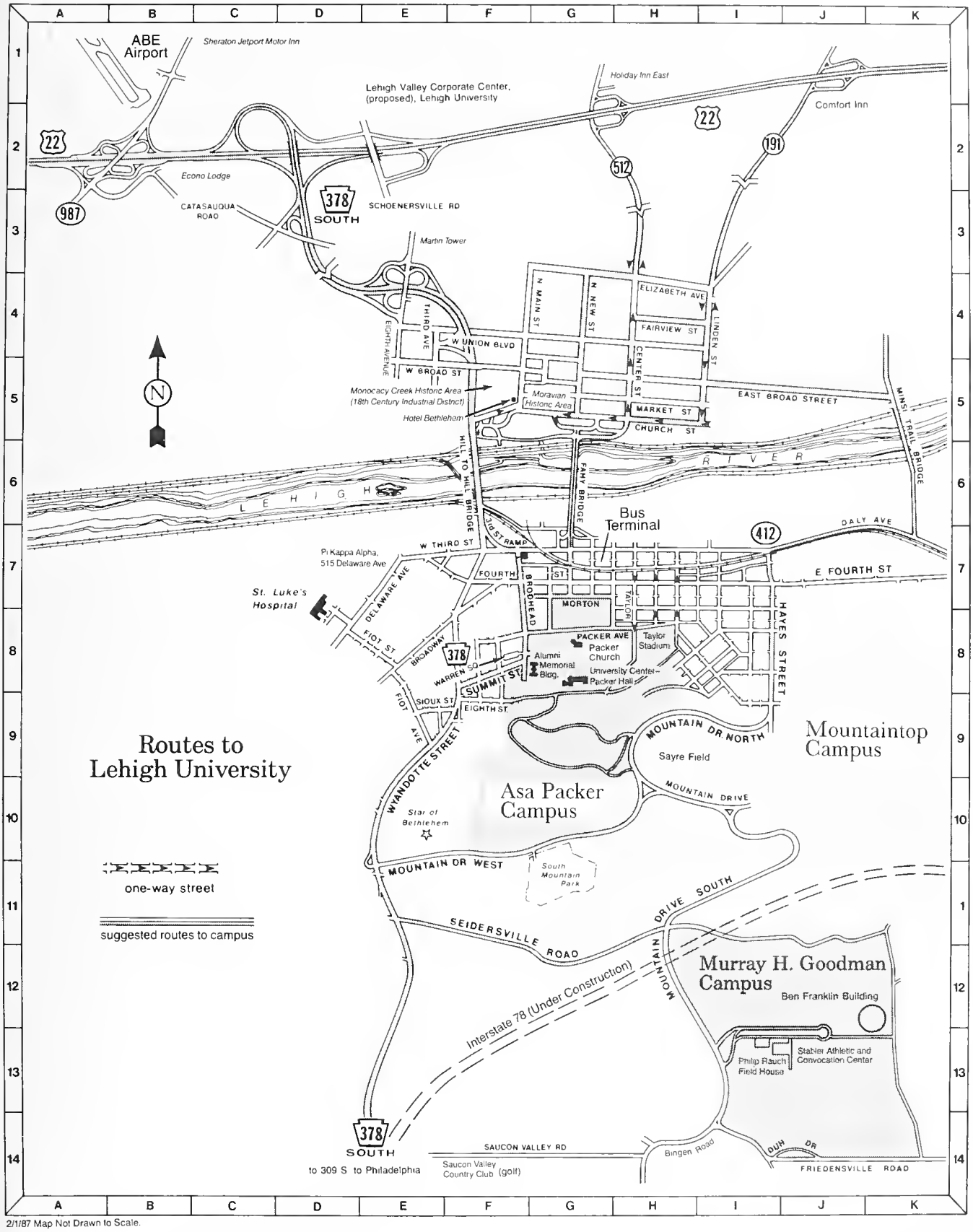
**Driving from New York City area.** Take Route 22 west and leave at the last Bethlehem exit, Route 378. Route 378 heads only south; continue for 3.6 miles and when you cross the bridge over the Lehigh River, be careful to stay in the left lane. Turn left at the traffic light for Third St. at the far end of the bridge; continue one block to the traffic light at Brodhead Ave., and turn right. Continue three blocks until you see the Alumni Memorial Building, location of the office of admission, on your left. You may park for free in front of the building.

**Driving from western points.** Take Route 22 east, exiting at Route 378, which is the first of three Bethlehem exits. Continue south as described above.

**From Philadelphia.** Take Route 309 (Bethlehem Pike) north to Center Valley. Turn right onto Route 378 and go over the first mountain you see. About halfway down the far side of the mountain (after a total of 5.4 miles on Route 378), turn right onto Summit St. Continue for about two blocks, to the point where Summit St. terminates at Brodhead Ave. The university is directly ahead. Continue down Brodhead just beyond Packer Ave. and park in the lot on your left.

An alternative is to take the Northeast Extension of the Pennsylvania Turnpike north to Exit 32, then head east for 3.5 miles on Route 663. Turn left onto Route 309 in Quakertown. Continue on Routes 309 and 378 as described above.

**Deliveries.** Commercial carriers should make inquiries regarding deliveries with appropriate offices. Road restrictions may apply.

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# Asa Packer Campus

The Asa Packer Campus, Lehigh's original campus, contains most of the university's academic buildings, residential facilities and offices. The guide below locates a few of the more frequently visited offices.

**Admission**—Alumni Memorial Building C-5
**Bursar**—Alumni Memorial Building C-5
**Career Services**—Christmas-Saucon Hall F-4
**Chaplaincy Services**—Johnson Hall E-6
**College of Arts and Science**—Maginnes Hall D-3
**College of Business and Economics**—Drown Hall F-6
**College of Engineering and Applied Science**—Packard Laboratory D-4
**Counseling Service**—Johnson Hall E-6
**Dean of Students**—Packer Hall E-6
**Financial Aid**—218 W. Packer Ave. B-4
**Graduate School**—Whitaker Laboratory F-3
**Health Center**—Johnson Hall E-6
**President's Office**—Alumni Memorial Building C-5
**Registrar**—Alumni Memorial Building C-5
**Research**—Whitaker Laboratory F-3 (headquarters)
**Residential Services**—Rathbone Hall J-5
**University Police**—Packer Hall, the university center E-6

### University Facilities

Alumni Memorial Building C-5
Audio-Visual Center F-4 annex
Chandler-Ullmann Hall F-4
Christmas-Saucon Hall F-4
Computer Store C-5
Computing Center E-3
Coppee Hall F-6
Coxe Laboratory G-6
Drown Hall F-6
E.W. Fairchild-Martindale Library and Computing Center E-3
Fraternity Management Association (516 Brodhead) B-4
Fritz Engineering Laboratory and Annex G-4
Grace Hall H-5, 6
Johnson Hall E-6
Lamberton Hall F-6
Linderman Library F-5
Maginnes Hall D-3
Mart Science and Engineering Library E-3
Harold S. Mohler Laboratory B-4
Seeley G. Mudd Building F-3
Neville Hall F-3
Packard Laboratory D-4
Packer Hall, the university center E-6
Packer Memorial Church E-4
Philosophy Building E-4
Physics/Physical Sciences G-4
President's House D-5
Price Hall G-6
Rathbone Hall J-5
Office of Research B-4
Sherman Fairchild Center for the Physical Sciences G-4
Sinclair Laboratory F-3
Small Business Development Center E-2
Taylor Gymnasium H-5
Community Services Volunteer House (532-534 Brodhead) B-5
Whitaker Laboratory F-3
Wilbur Drama Workshop G-4
Williams Hall G-5

### Residential Buildings

Brodhead House C-2
Beardslee House K-5
Carothers House K-5
Centennial I houses J-6, K-5
Centennial II houses K-4, 5
Congdon House (Alpha Phi) K-5
Dravo House G-7
Drinker House G-7
Emery House (Gamma Phi Beta) K-5
German House, 210 Warren Square B-5
Gipson Residential College, Murray H. Goodman Campus D-4
Hartman Residential College, Murray H. Goodman Campus D-4
Hillel House, 214 Summit St. B-5
International House, 220 Warren Square B-5
Leavitt house (Alpha Gamma Delta) K-6
McClintic-Marshall House J-6
McConn House (Alpha Omicron Pi) J-6
More Residential College, Murray H. Goodman Campus C-4
Packer House, 217 W. Packer Ave. B-3
Palmer House K-5
Richards House H-7
Saucon Village Apartments, Murray H. Goodman Campus CD-4
Severs House, Murray H. Goodman Campus C-4
Smiley House (Kappa Alpha Theta) J-6
Stevens House K-4
Stoughton House K-4
222 Summit House K-4
Taylor Residential College E-7
Thornburg House (Delta Gamma) J-6
Trembley Park apartments D-6
Williams House K-5

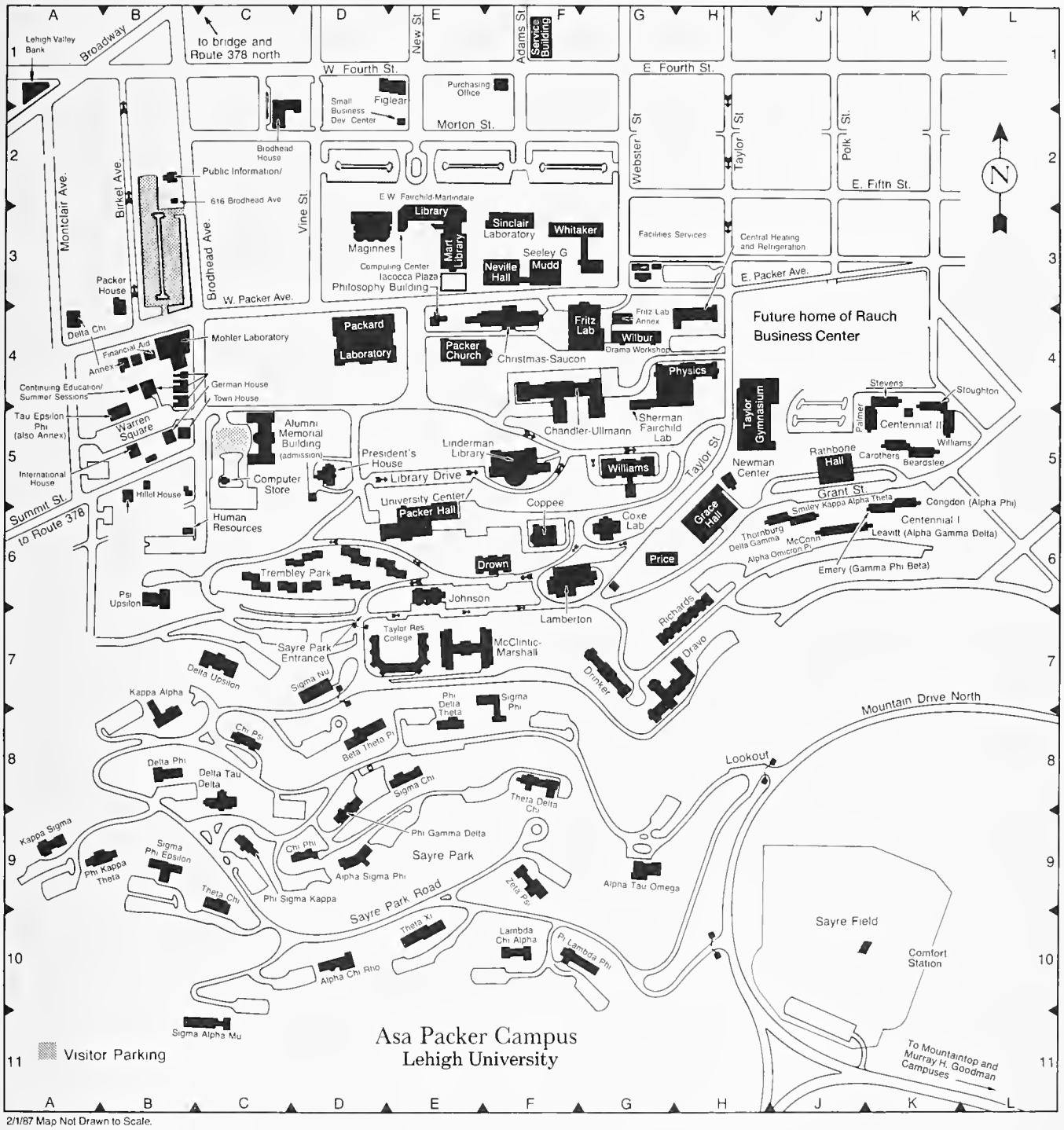
### Fraternity Residences

Alpha Chi Rho D-10
Alpha Epsilon Pi, 308 W. Packer Ave.
Alpha Sigma Phi D-9
Alpha Tau Omega G-9
Beta Theta Pi D-8
Chi Phi D-9
Chi Psi C-8
Delta Chi, 233 W. Packer Ave. A-4; annex 230 W. Packer Ave.
Delta Phi B-8
Delta Tau Delta C-8
Delta Upsilon C-7
Kappa Alpha B-8
Kappa Sigma A-9
Lambda Chi Alpha F-10
Phi Delta Theta E-8
Phi Gamma Delta D-9
Phi Kappa Theta A-9
Phi Sigma Kappa C-9
Pi Kappa Alpha, 545 Delaware Ave.
Pi Lambda Phi F-10
Psi Upsilon C-7
Sigma Alpha Mu C-11
Sigma Chi E-8
Sigma Nu D-7
Sigma Phi F-7
Sigma Phi Epsilon B-9
Tau Epsilon Pi, 227-229 Warren Square B-5; annex 216 Warren Square
Theta Chi C-9
Theta Delta Chi F-8
Theta Xi E-10
Zeta Psi F-9

### Sorority Residences

Alpha Gamma Delta (Leavitt House) J-6
Alpha Omicron Pi (McConn House) J-6
Alpha Phi (Congdon House) K-5
Delta Gamma (Thornburg House) J-6
Gamma Phi Beta (Emery House) K-6
Kappa Alpha Theta (Smiley House) J-6

# Lehigh University

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# Mountaintop Campus

The 742-acre Mountaintop Campus, which includes a 72-acre research complex, was acquired by Lehigh from Bethlehem Steel Corp. in 1986. Lehigh owns five of the eight buildings in the research complex.

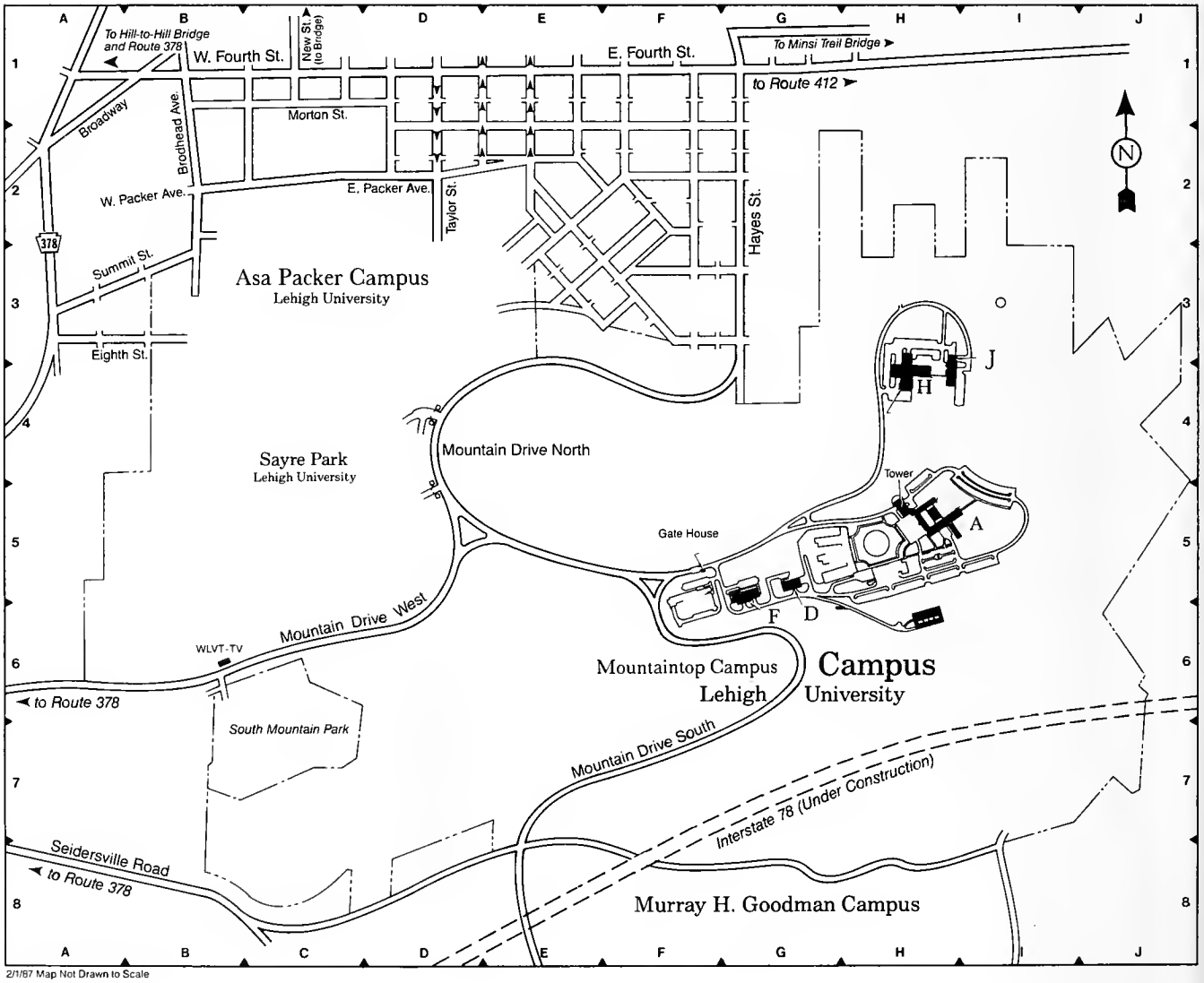
Building A—H-5
- Biochemistry
- Center for Molecular Bioscience and Biotechnology
- College of Education
- Department of Chemical Engineering
- Division of Biochemistry
- Division of Bioscience
- Educational Technology Center
- Emulsion Polymers Institute
- Iacocca Institute
- Molecular Biology
- Office of Community Relations
- Process Modeling and Control Center

Building D—G-5
- Central Heating and Refrigeration

Building f—G-5
- North East Tier Ben Franklin Advanced Technology Center (incubator companies)

Building H—H-4
- Engineering Research Center for Advanced Technology for Large Structural Systems (ATLSS)

Building J—H-4
- Central Stores and Receiving
- Mailing and Printing Services

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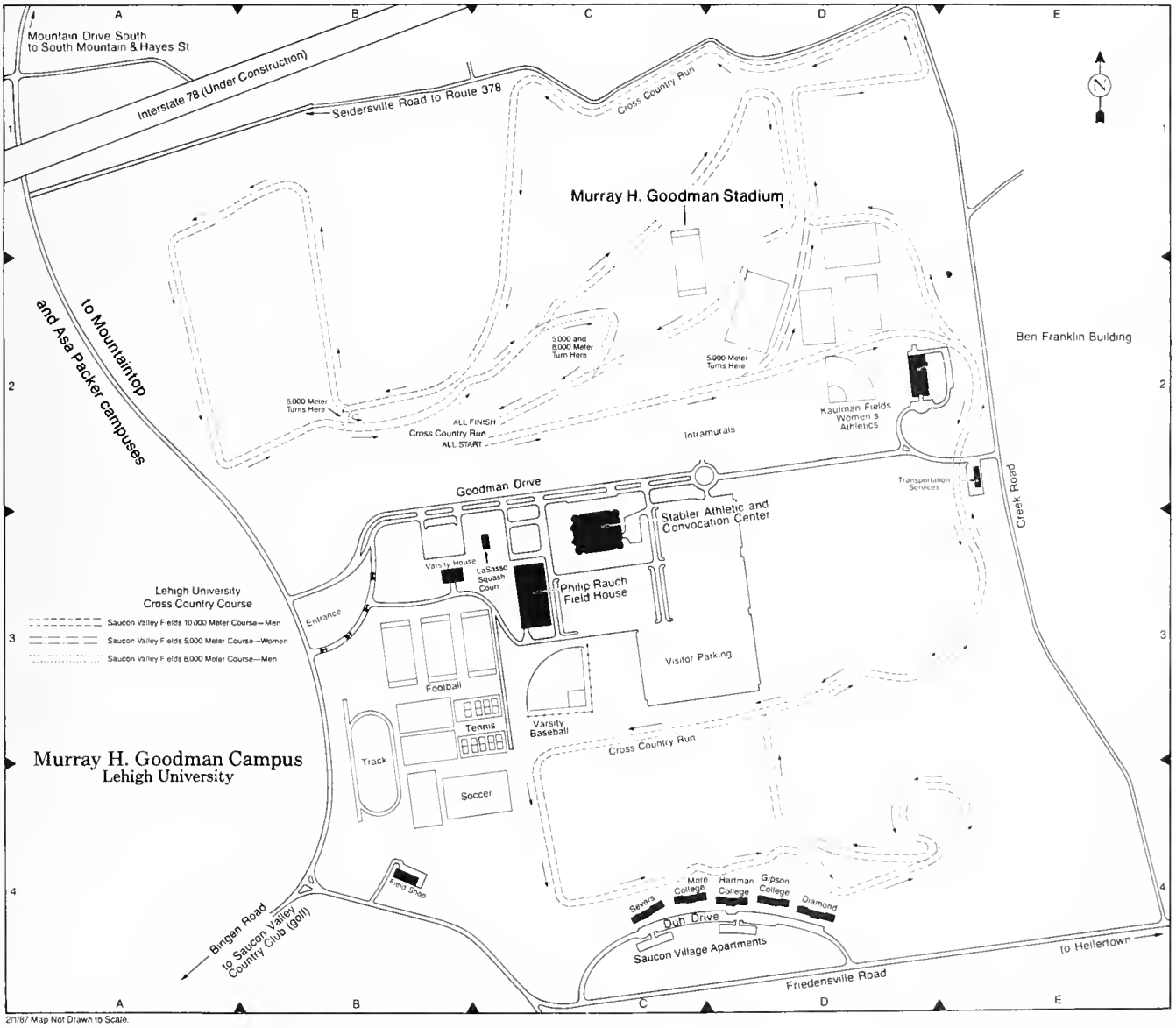
# Murray H. Goodman Campus

The Murray H. Goodman Campus, located in the Saucon Valley area south of the Asa Packer and Mountaintop campuses, offers athletic fields and tennis courts. The headquarters of North East Tier Ben Franklin Advanced Technology Center also is on the site.

Ben Franklin Building D-2
Murray H. Goodman Stadium C-2
LaSasso Squash Court C-3
Philip Rauch Field House C-3
Saucon Village Apartments CD-4
  Diamond
  Gipson Residential College
  Hartman Residential College
  More Residential College
  Severs
Stabler Athletic and Convocation Center C-3
Transportation Services E-2
Varsity House locker facility B-3

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# Recognition of Achievement

At the end of each semester, the dean of students publishes a list of all regular undergraduates who during that semester achieved a scholastic average of 3.50 or better and carried at least twelve credit hours of regularly graded courses (A, B, C, D, F). This is the dean's list.

Other student prizes and awards are announced at commencement exercises held on both Founder's Day, which is the second Sunday in October, at the Honors Convocation for juniors and seniors held in the spring, and on University Day in May or June. A description of the annual prizes and awards follows.

**Alpha Pi Mu Prize.** The honorary fraternity in industrial engineering awards each year an industrial engineers' handbook to a high-ranking sophomore with demonstrated interest in the industrial engineering curriculum.

**Alumni Association Prizes.** Funds are provided for three cash prizes. Prizes are awarded to the highest-ranking juniors in each undergraduate college.

**American Chemical Society Award.** The Lehigh Valley section of the American Chemical Society awards a membership in the society and a subscription to its journal to an outstanding senior in chemistry or chemical engineering.

**Medal of the Philadelphia Chapter, American Institute of Chemists.** This medal is awarded to the academically highest ranking senior majoring in chemistry or chemical engineering.

**American Society of Civil Engineers Prize.** The Lehigh Valley Section of the American Society of Civil Engineers offers a prize of a junior membership in the society to the outstanding senior in civil engineering holding membership in the student chapter.

**American Society of Mechanical Engineers Associate Membership Prize.** The Anthracite-Lehigh Valley Section of the American Society of Mechanical Engineers awards to an outstanding member of the Lehigh University Student Section ASME an associate membership for one year in the parent society.

**American Society for Testing Materials Student Memberships Prize.** Four student memberships are awarded to students who in their junior year have demonstrated interest and meritorious work in the engineering courses that are related to the ASTM.

**Ferdinand P. Beer Award.** An outstanding senior in mechanics receives this award named for the university distinguished professor emeritus of mechanical engineering and mechanics.

**Bethlehem Fabricators Award.** This tuition award is made to the junior who has shown the most improvement in academic achievement over sophomore and junior years.

**The Robert W. Blake Memorial Prize.** This prize is awarded at Founder's Day exercises to a freshman who has completed one year of studies in the College of Arts and Science and who is recommended by the college faculty as the most outstanding in high scholastic achievement and in promise of leadership.

**Nelson Leighton Bond 1926 Memorial Award.** This award is made to an outstanding sophomore on the basis of character, leadership, and scholastic achievement but not financial need. Nelson L. Bond was a prominent alumnus.

**The John B. Carson Prize.** A prize was established by Mrs. Helen Carson Turner, of Philadelphia, in memory of her father, John B. Carson, whose son, James D. Carson, was a graduate of the civil engineering curriculum in 1876. It is awarded to the senior in civil engineering who shows the most marked excellence in professional courses.

**The William H. Chandler Prizes in Chemistry.** Four prizes, one in each class, for excellence in the chemistry and chemical engineering curricula were established by Mrs. Mary E. Chandler, widow of Dr. William H. Chandler, who was professor of chemistry from 1871 until his death in 1906.

**The N.I. Stotz and D.E. Rickert Choral Cup.** The choral cup provided by Norman I. Stotz, Jr., '53, and Donald E. Rickert, '53, is awarded to the outstanding senior participating in the choral organizations of the music department.

**The R.K. Burr and J.D. Kirkpatrick Concert Cup.** The concert cup provided by Richard K. Burr, '53, and J. Donald Kirkpatrick, '55, is awarded to the outstanding senior(s) participating in the band or other instrumental organizations of the music department.

**The Cornelius Prize.** The Cornelius Prize established by William A. Cornelius, M.S. 1889, and endowed by a bequest by his widow, Mrs. Eleanor R.W. Cornelius, is awarded to the senior student in mechanical engineering who is judged to have profited most by opportunities at Lehigh. The award is based 70 percent on scholarship, 20 percent on attainment in general culture, and 10 percent on development in personality. To be eligible, a student's scholastic standing must be in the top quarter of the class in the College of Engineering and Applied Science.

**Robert Cutler Senior Cup.** To a senior member of the choir for his or her outstanding service to the choir. Robert B. Cutler is professor emeritus of music.

**Grant C. Danzer Memorial Prize Funds.** The award is based upon academic achievement, involvement in university and community activities, determination and high regard for fellow students and faculty members.

**Alpha A. Diefenderfer Award.** In recognition of the late Professor A.A. Diefenderfer's long service as faculty adviser to the organization, the Lehigh University Chemical Society established this award for the highest-ranking junior in analytical chemistry.

**Aurie N. Dunlap Prize in International Relations.** The prize is awarded by the international relations department to an outstanding senior in international relations. Among the criteria used to select the winner (or winners) are the following: cumulative average in international relations courses (minimum 3.5 cumulative average is required); over-all scholarly standing; number of international relations courses taken; activities on the campus related to appreciation of international relations by the Lehigh community; and the contribution to university life. Dr. Dunlap was professor of international relations.

**The Philip Francis du Pont Memorial Prize in Electrical Engineering.** The Philip F. du Pont Memorial Prize Fund was established in 1929 by L.S.

Horner, 1898. The income of this fund is awarded in the way of prizes, two-thirds to the highest-ranking senior and one-third to the second-highest-ranking senior in electrical engineering.

**Jonathan B. Elkus Freshman Music Cup.** This is awarded to a full-time freshman on the basis of membership in marching and concert band, over-all musical ability, demonstrated leadership, and exceptional psyche. Elkus was director of the marching band.

**Eta Kappa Nu Prize.** The honorary fraternity in electrical engineering awards a handbook in electrical engineering to the highest-ranking freshman in electrical and computer engineering.

**Financial Executive Award.** The award is made to a first-semester senior awarded on basis of outstanding achievement in accounting and/or finance, promise of future success and intent to seek a career in corporate accounting or financial management.

**Foreign Student Awards.** The award is made to a junior or sophomore who maintains a 3.0 or 3.5 average in the languages and 3.0 overall average.

**Fraternity Alumni Advisory Council Scholarship Improvement Award.** This trophy is awarded to the fraternity chapter whose scholastic average for the year is most improved over the previous year.

**Joseph C. Gabuzda Jr. Memorial Award.** The award is presented to a deserving junior in electrical or computer engineering who has shown outstanding promise intellectually and in leadership qualities.

**German Prize.** The prize is awarded to seniors who are excellent in German language or culture or performing outstanding service to German culture and civilization.

**Gipson Institute Undergraduate Essay Prize.** This prize is awarded for the best undergraduate paper dealing with an 18th Century topic. The Lawrence Henry Gipson Institute for Eighteenth-Century Studies was endowed by a Lehigh professor who won the Pulitzer Prize.

**The Gold-Hansen Trophy.** Provided by Stephen R. Gold, '60, and Robert A. Hansen, '60, the trophy is awarded to a student of at least four semesters' standing with the band who has shown outstanding merit in other ways than musical or marching performance.

**Malcolm J. Gordon, Jr., Physics Prize.** An award is made to the highest-ranking sophomore physics major, with some extracurricular activity.

**Handwerk Prize.** The award is made to a student for outstanding achievement in the fields of chemistry, metallurgy or geological sciences.

**The Bill Hardy Memorial Prize.** An award is given by Mr. and Mrs. D. Edson Hardy in memory of their son. The recipient is the junior who most nearly reflects the qualities that typified Bill Hardy, who was outstanding in many activities, academic and otherwise.

**George D. Harmon Memorial Award.** An award to an outstanding senior in the history department is named for a former professor of history.

**Haskins and Sells Foundation Award.** An award of $500 is made to an accounting student in the College of Business and Economics or the College of Arts and Science who after three years has demonstrated excellence in scholarship, professional potential, extracurricular activities, and moral character.

**David Hellekjaer Memorial Award.** The friends of Dave Hellekjaer, '80 (1958-1980), created an award in his memory. It is presented to a senior who best exemplifies his characteristics, viz.: vigorous participation in sports, dedicated commitment to the study of the natural or physical sciences (biology, geology, environment science, physics or chemistry), and loyalty and contribution to a fraternity or sorority.

**Joseph C. Hendrzak Memorial Award.** The award is made to an outstanding senior in military science.

**Donnel Foster Hewett Award.** This is awarded to the senior in geology or geological sciences who has demonstrated the greatest potential for a professional career in the earth sciences.

**The Harold J. Horn Prize.** The heirs of Harold J. Horn, 1898, established a fund, the income of which is used in the award of a first and second prize, for the two highest-ranking juniors in electrical engineering.

**Mary O. Hurley Women's Athletic Award.** To a woman undergraduate who demonstrates sportsmanship, a cooperative attitude, and an enjoyment of sports with her fellow students.

**Institute of Internal Auditors Award.** The award is made to an outstanding senior interested in auditing.

**Kahn Memorial Award.** The award is made to a senior outstanding in metallurgy and materials engineering.

**Kappa Alpha Glee Club Senior Cup.** The cup is awarded to a senior for outstanding service to the Glee Club.

**The Andrew Wilson Knecht III Memorial Award.** This award is made to the member of the mechanical engineering class graduating in May or June who has exhibited the greatest potential for applying technical training to practical application. The award is an engraved medallion.

**Kodak Scholar Awards.** These awards are made to second-semester freshmen each year who plan to major in engineering fields other than civil engineering. They cover 75 percent of tuition costs.

**Lt. General Fred Kornet, Jr. Award.** The award is made to a graduating senior in military science whose academic performance and AFROTC achievement indicate the greatest potential for sustained professional excellence in a military career.

**Arnie Lasser Award.** This award is made to an outstanding undergraduate athlete in football or wrestling from the New York metropolitan area, regardless of need.

**Lehigh Women's Club Prize.** A junior with academic excellence and outstanding service to Lehigh is selected.

**James J. Mahlbacher Prize.** A football player of outstanding ability is chosen upon recommendation of coach and athletic directory.

**Mathematics Faculty Award.** This award, made possible by a fund established by the faculty members of the department of mathematics, is made to an outstanding junior majoring in mathematics or statistics.

**Joseph A. Maurer Classics Prize.** The award made to

graduating seniors in two areas: first, to the major in classics for excellence in the Latin and Greek languages, and second, to the major in classical civilization for excellence in that aspect of classical studies. Joseph A. Maurer is professor emeritus of classics.

**Merck Index Award.** A copy of the Merck Index is awarded by Merck and Co., Inc., to a senior in chemistry who is an outstanding student; who has been active in student society affairs; and who has promise of a successful career in chemistry in the judgment of the faculty of the chemistry department.

**J. Robert Munford Award.** The award is made to the geology senior who has shown the greatest improvement in over-all performance.

**National Association of Accountants Award.** The award is made to an outstanding accounting student.

**The Elizabeth Major Nevius Award.** Established by Walter I. Nevius, '12, "in loving memory of his wife, who profoundly admired young men of diligence, intelligence, aggressiveness and sterling character," the award is made to individuals who have entered their fifth year of work at Lehigh (whether it be a second undergraduate degree or a graduate degree after a first undergraduate degree). The winners are determined by the Committee on Undergraduate Awards and Prizes on the basis of leadership, citizenship and scholarship.

**Class of 1904 Award.** The award is presented to an outstanding member of the junior class on the basis of character, scholarship, qualifications indicating promise of future leadership, and extracurricular activities.

**C.J. Osborn Award in Metallurgy and Materials Engineering.** The award is presented to a senior in the department of metallurgy and materials engineering who is deemed worthy of recognition by the faculty of the department.

**Pat Pazzetti Award.** The award made in honor of Vincent J. "Pat" Pazzetti, Jr., '15, is presented to a Lehigh football player of outstanding ability.

**The Pennsylvania Institute of Certified Public Accountants Prize.** The plaque goes to the senior in the College of Business and Economics majoring in accounting who is outstanding in academic achievement and leadership.

**Phi Sigma Kappa Scholarship Cup.** This cup, awarded to the fraternity having the highest scholastic average for the preceding year, becomes the permanent property of the fraternity winning it for three successive years. The original cup was provided by an alumnus of the Nu Chapter of Phi Sigma Kappa in 1923. Cups are provided by the local chapter.

**Pi Tau Sigma Prize.** The honorary fraternity in mechanical engineering awards a mechanical engineers' handbook to the highest-ranking sophomore in mechanical engineering.

**Leonard P. Pool Memorial Award.** This award is made annually to a junior or senior student exhibiting entrepreneurial talents. Mr. Pool was chairman of Air Products and Chemicals, Inc.

**The Allen S. Quier Prize in Metallurgy.** A prize has been provided by the daughters of the late Allen S. Quier in memory of their father, to be awarded to the senior who is adjudged by the staff of metallurgy and materials engineering to have made the most progress in that curriculum. While high scholastic standing is a requisite, the prize is awarded on the basis of progressive achievement in scholastic work, rather than an average rating.

**Bosey Reiter Leadership Cup.** This award is given to the student whose leadership contributes primarily to the best interests of the university. Leadership is defined chiefly as moral character and combines intellectual ability and common sense. High scholarship and athletic achievements are included as cases of leadership, but neither is necessary or sufficient alone.

**Robert Ridgway Senior Prize.** This prize is awarded to the senior in the College of Engineering and Applied Science with the highest cumulative average.

**Col. Edward W. Rosenbaum Award.** The award, in honor of Robert Rosenbaum, '17, is awarded each year to recognize the outstanding senior aerospace studies student.

**Margaret B. Savic Tennis Award.** The award is made to the most valuable player on the tennis team.

**William H. Schempf Award.** This award is made annually to the freshman who has shown outstanding ability and interest beyond the requirements of a normal freshman bandsman. It is made in honor of a former head of the music department by the Beta Sigma chapter of Theta Chi social fraternity.

**The Senior Band Plaque.** The plaque was established by the seniors on the executive committee of the Lehigh University Band to honor a member or members of the senior class of the band who have given outstanding performances in both marching and concert seasons for four years and who have not served in a major administrative capacity in the band.

**T. Edgar Shields Band Cup.** This is awarded to the student who has made the greatest musical contribution to the band.

**T. Edgar Shields Glee Club Cup.** This cup is awarded to the student who made the greatest musical contribution to the Glee Club.

**John S. Steckbeck Award.** This award is presented annually to the most outstanding woman freshman athlete in good academic standing. It honors the memory of its namesake, who was director of intramurals.

**Alan H. Stenning Award.** A prize is awarded to a senior mechanical engineering or mechanics student for excellence in an undergraduate engineering project.

**Bradley Stoughton Student Award.** This award is given to an outstanding senior in the metallurgy and materials engineering department. It consists of a certificate and cash award.

**Tau Beta Pi Prize.** The engineering honorary fraternity awards a prize to the engineering sophomore having the highest scholastic average.

**Thornburg Mathematics Prize.** This prize is made possible through a bequest by the late W.P. Tunstall, '03, in honor of Charles L. Thornburg, who was professor of mathematics. The prize, consisting of a credit to purchase books in the field of mathematics or allied disciplines at the bookstore, is awarded to the senior with the most outstanding record in advanced courses in mathematics.

**Trustees' Scholarship Cup.** The trustees have provided this cup, which is awarded for one year to the liv-

ing group having the highest scholarship average for the preceding year. The cup becomes the permanent property of any living group winning it for three consecutive years.

**Harry M. Ullmann Chemistry Prize.** The prize goes to the highest-ranking seniors in chemistry and chemical engineering.

**Undergraduate Merit Award(s) of the Lehigh University Alumni Association.** Seniors who by exemplary character, personality, scholarship, and participation in extracurricular activities represent(s) the highest traditions of Lehigh University are honored.

**University Service Award.** This award is given to the senior who has been adjudged to have contributed most during his or her career at Lehigh to promote student body unity, campus cooperation for worthy objectives, and loyalty to the alma mater. It is expected that the student selected shall be of sound character and satisfactory scholarship.

**John R. Wagner Award.** This award goes to the junior student in mechanical engineering whose scholastic record is the highest in his or her class in the freshman and sophomore years and whose character and life purposes are deemed deserving and worthy.

**Wall Street Journal Award.** This is awarded to a senior finance major primarily on the basis of scholarship.

**William Whigham, Jr., Memorial Prize.** This is awarded to the top-ranking freshman in engineering, based on high cumulative average in the first two semesters.

**Elisha P. Wilbur Prizes.** A fund was established by E.P. Wilbur, trustee from 1872 until 1910, for distribution in prizes as the faculty might determine. The income from this fund provides two awards, as follows: *Wilbur Mathematics Prizes.* A first and second prize is awarded to the two highest-ranking freshman engineers in mathematics. *Wilbur Scholarship Prize.* This prize is awarded to the sophomore with the best average.

**Williams Prize in Creative Writing.** A prize is awarded to the author of a meritorious short story, play, or poem submitted by an undergraduate.

**Williams Prize in Dramatics.** A prize is awarded to an undergraduate whose interpretation of a role in production is judged most outstanding.

**Williams Prizes in English.** Professor Edward H. Williams, Jr., Class of 1875, established prizes for excellence in English composition and public speaking. First, second and third prizes are awarded by the faculty to students in their freshman, sophomore, and junior years.

**Williams Prize in Interpretive Reporting.** A prize is awarded to an undergraduate for meritorious reporting, published or unpublished, intended to interpret the meaning of events or developments that are significant in the life of the university.

**Williams Senior Prizes.** These prizes are awarded by the faculty on the recommendation of the committee on Williams Prizes. First, second, and third prizes are awarded in each of the five fields of economics, English, philosophy, psychology, and history and government for dissertations submitted by seniors on or before April 15. The committee on Williams Prizes publishes a list of recommended subjects for dissertations; but a senior may submit a dissertation on any other subject in the respective field if the subject has received the approval of the committee. Each senior entering the competition submits to the committee his or her choice of subject and plan of work by November 15. The awards are made by the faculty upon recommendation of the committee, but no award is made if a dissertation does not meet the standards of merit established by the committee. This standard includes such points as excellence in thought, plan, development, argument, and composition.

**The Theodore B. Wood Prize.** A prize is awarded under the terms of the will of Theodore Wood to the mechanical engineering student who has made the greatest scholastic improvement during the first two years of the college course.

# Academic Departments

## *College of Arts and Sciences*

Art and Architecture
Biology
Chemistry
Classics
English
Geological Sciences
Government
History
International Relations
Journalism
Mathematics
Modern Foreign Languages
Music
Philosophy
Physics
Psychology
Religion Studies
Social Relations
Theatre

## *College of Business and Economics*

Accounting
Economics
Finance
Law and Business
Management
Marketing

## *College of Education*

Counseling Psychology, School Psychology and Special Education
Leadership, Instruction and Technology

## *College of Engineering and Applied Science*

Chemical Engineering
Civil Engineering
Computer Science and Electrical Engineering
Industrial Engineering
Materials Science and Engineering
Mechanical Engineering and Mechanics

## Registration

| | spring 1987 | summer 1987 | fall 1987 | spring 1988 | summer 1988 | fall 1988 |
|---|---|---|---|---|---|---|
| undergraduate | 4344 | 671 | 4670 | 4512 | 744 | 4615 |
| graduate students | 1794 | 939 | 1927 | 1875 | 880 | 1954 |
| totals | 6138 | 1610 | 6597 | 6387 | 1624 | 6569 |

## Graduate Enrollment

A total of 1,492 men and 462 women took graduate studies at the university in the fall of 1988, for a total of 1,954 students. A breakdown by area of study and degree sought is provided below, listing both part-time and full-time students.

Applied Mathematics, 7 M.S., 9 Ph.D.; Applied Mechanics, 3 M.S., 8 Ph.D.; Applied Social Research, 4 Ph.D.; Biology, 16 M.S., 1 M.A., 10 Ph.D.; Business & Economics, 7 M.S., 28 Ph.D.; Business Administration, 331 M.B.A.; Chemical Engineering, 59 M.S., 2 M.Eng., 48 Ph.D.; Chemistry, 27 M.S., 48 Ph.D.; Civil Engineering, 48 M.S., 1 M.Eng., 25 Ph.D.; Computer Science, 51 M.S., 22 Ph.D.; Community Counseling, 25 M.Ed., 1 D.Ed.; Counseling Psychology, 22 Ph.D.; Counseling, 1 Ph.D., 10 M.Ed., 5 D.Ed.; Educational Administration, 47 M.Ed., 23 D.Ed.; Educational Technology, 49 M.S., 19 D.Ed.; Education, 5 M.A., 1 M.Ed., 5 D.Ed.; Electrical & Computing Engineering, 1 M.S.; Electrical Engineering, 114 M.S., 35 Ph.D.; Elementary School Counseling, 5 M.Ed.; Elementary Education, 1 M.A., 40 M.Ed., 8 D.Ed.; English, 27 M.A., 14 Ph.D.; Foundations of Education, 2 D.Ed.; Geology, 7 M.S., 7 Ph.D.; Government, 11 M.A., 1 D.A.; History, 10 M.A., 3 Ph.D.; Human Development, 1 M.Ed.; Industrial Engineering, 30 M.S., 2 M.Eng., 24 Ph.D.; Information Science, 1 Ph.D.; Management Science, 8 M.S.; Manufacturing Systems Engineering, 34 M.S.; Materials Science Engineering, 38 M.S., 6 M.Eng., 37 Ph.D.; Mathematics, 12 M.S., 1 M.A., 21 Ph.D.; Mechanical Engineering, 50 M.S., 22 Ph.D.; Metallurgy and Material Engineering, 1 M.S.; Molecular Biology, 1 Ph.D.; Physics, 17 M.S., 35 Ph.D.; Physiological Chemistry, 1 M.S.; Polymer Science Engineering, 2 M.S., 23 Ph.D.; Psychoeducational Studies, 5 Ph.D.; Psychology, 1 M.S., 16 Ph.D.; Public Administration, 8 M.P.A.; Reading, 23 M.Ed., 17 D.Ed.; Secondary Education, 19 M.A., 16 M.Ed.; School Counseling, 2 M.Ed.; Secondary School Counseling, 10 M.Ed.; Special Education, 2 Ph.D., 50 M.Ed., 7 D.Ed., 2 Ed.S.; School Psychology, 4 Ph.D., 15 Ed.S.; Social Relations, 1 M.S., 10 M.A.

In addition, 126 students were enrolled in various programs, but had not designated the graduate degree sought.

## Fall 1988

| | freshmen | sophomores | juniors | seniors | total |
|---|---|---|---|---|---|
| Accounting | | 1 | 44 | 90 | 135 |
| American Studies | | | 2 | 1 | 3 |
| Applied Science | | 1 | 6 | 5 | 12 |
| Architecture | | 3 | 25 | 22 | 50 |
| Art | | | 6 | 2 | 8 |
| Arts-Engineering | 34 | 23 | 2 | | 59 |
| Arts and Science | 516 | 500 | 64 | 1 | 1081 |
| Behav & Neural Biol | | | 10 | 11 | 21 |
| Biochemistry | | | 4 | 2 | 6 |
| Biology | | 4 | 22 | 31 | 57 |
| Business | 197 | 276 | 185 | 18 | 676 |
| Chemical Engineering | | 29 | 31 | 36 | 96 |
| Chemistry | | | 1 | 7 | 8 |
| Civil Engineering | | 39 | 39 | 47 | 125 |
| Classical Civilizations | | | 2 | 1 | 3 |
| Classics | | | | 1 | 1 |
| Cognitive Science | | | 2 | | 2 |
| Computer Engineering | | 33 | 19 | 24 | 76 |
| Computer Science-arts | | 3 | 22 | 20 | 45 |
| Computer Science-csee | | 8 | 21 | 15 | 44 |
| Economics | | 2 | 50 | 40 | 92 |
| Electrical Engineering | 1 | 85 | 67 | 110 | 263 |
| Engineering | 406 | 37 | 14 | 2 | 459 |
| Engineering Mechanics | | 1 | | 1 | 2 |
| Engineering Physics | | 3 | 4 | 8 | 15 |
| English | | 6 | 27 | 40 | 73 |
| Environmental Science and Resource Management | | 1 | 1 | 3 | 5 |
| Finance | | | 25 | 118 | 143 |
| Foreign Careers | | | 3 | 17 | 20 |
| French | | | | 1 | 1 |
| Fundamental Science | | | 1 | | 1 |
| General College Division | | | | | 21 |
| Geological Sciences | | | 1 | 4 | 5 |
| Geology | | | 1 | 1 | 2 |
| German | | | 2 | | 2 |
| Government | | | 31 | 25 | 56 |
| History | | 3 | 4 | 9 | 16 |
| Industrial Engineering | | 45 | 47 | 80 | 172 |
| International Careers | | 5 | 16 | 4 | 25 |
| International Relations | | 2 | 37 | 37 | 76 |

| | | | | | |
|---|---|---|---|---|---|
| Journalism | | | 12 | 13 | 25 |
| Journalism/Science Writing | | | 1 | 4 | 5 |
| Management | | 1 | 3 | 11 | 15 |
| Marketing | | 1 | 12 | 62 | 75 |
| Materials Science & Engineering | | 17 | 7 | 6 | 30 |
| Mathematics | | | 10 | 6 | 16 |
| Mechanical Engineering | 2 | 110 | 107 | 100 | 319 |
| Biology | | 2 | 3 | 7 | 12 |
| Music | | | | 1 | 1 |
| Natural Science | | | 2 | 2 | 4 |
| Philosophy | | | 6 | 10 | 16 |
| Premed Science | | | | 2 | 2 |
| Psychology | | 5 | 36 | 37 | 78 |
| Social Relations | | | 15 | 21 | 36 |
| Spanish | | | 3 | | 3 |
| Statistics | | 1 | | | 1 |
| Theatre | | | 3 | 1 | 4 |
| Urban Studies | | 1 | 6 | 9 | 16 |

# Geographical Distribution

## All figures are for fall, undergraduates only.

| | 1987 | 1988 |
|---|---|---|
| Alabama | 1 | 1 |
| Alaska | 1 | 4 |
| Arizona | 1 | 2 |
| California | 25 | 26 |
| Colorado | 13 | 13 |
| Connecticut | 366 | 362 |
| Delaware | 26 | 25 |
| District of Columbia | 11 | 11 |
| Florida | 65 | 70 |
| Georgia | 18 | 18 |
| Hawaii | 4 | 1 |
| Illinois | 40 | 48 |
| Indiana | 2 | 1 |
| Iowa | | 1 |
| Kansas | 1 | 1 |
| Kentucky | 1 | 4 |
| Louisiana | 5 | 5 |
| Maine | 8 | 8 |
| Maryland | 133 | 133 |
| Massachusetts | 178 | 199 |
| Michigan | 10 | 15 |
| Minnesota | 7 | 6 |
| Missouri | 15 | 12 |
| Montana | 1 | 2 |
| Nebraska | 1 | |
| Nevada | | 1 |
| New Hampshire | 13 | 12 |
| New Jersey | 1358 | 1343 |
| New Mexico | | 1 |
| New York | 815 | 752 |
| North Carolina | 11 | 7 |
| Ohio | 52 | 54 |
| Oregon | 1 | 3 |
| Pennsylvania | 1298 | 1267 |
| Puerto Rico | 18 | 20 |
| Rhode Island | 16 | 17 |
| South Carolina | 4 | 4 |
| Tennessee | 3 | 2 |
| Texas | 17 | 18 |
| Vermont | 4 | 8 |
| Virginia | 42 | 49 |
| Virgin Islands | 1 | 2 |
| Washington | 1 | 1 |
| West Virginia | 4 | 5 |
| Wisconsin | 1 | 1 |
| total | 4592 | 4535 |

Foreign

| | 1987 | 1988 |
|---|---|---|
| Argentina | 1 | 2 |
| Australia | 2 | 2 |
| Austria | 1 | |
| Bahamas | | 1 |
| Bahrain | 1 | 1 |
| Belgium | | 1 |
| Bermuda | 1 | 1 |
| Brazil | 1 | 1 |
| Brunei | 1 | 1 |
| Canada | 4 | 2 |
| China (Peoples Republic) | | |
| Colombia | 6 | 4 |
| Costa Rica | 4 | 3 |
| Cyprus | 7 | 7 |
| Ecuador | 7 | 5 |
| El Salvador | 2 | 1 |
| England | | 2 |
| France | 2 | 3 |
| Germany | 2 | |
| Greece | 2 | 2 |
| Guatemala | 6 | 4 |
| Hong Kong | 7 | 5 |
| India | 8 | 8 |
| Indonesia | 1 | 1 |
| Italy | 4 | 4 |
| Japan | 6 | 6 |
| Kenya | 1 | 1 |
| Korea | 5 | 4 |
| Kuwait | 2 | 5 |
| Malaysia | 17 | 16 |
| Mexico | 2 | 1 |
| Morocco | 1 | 1 |
| Netherlands | 2 | 2 |
| Nigeria | | 1 |
| Norway | 1 | |
| Pakistan | 6 | 7 |
| Panama | 5 | 3 |
| Peru | 4 | 4 |
| Philippines | 6 | 6 |
| Qatar | 1 | |
| Singapore | 4 | 2 |
| Spain | 3 | |
| Sudan | | 2 |
| Swedan | | 4 |
| Switzerland | 3 | |
| Syria | | 1 |
| Taiwan | 2 | 4 |
| Thailand | 3 | 2 |
| Trinidad | 2 | 1 |
| Turkey | 7 | 6 |
| United Arab Emirates | 5 | |
| United Kingdom | 3 | 4 |
| Venezuela | 4 | 3 |
| Vietnam | | 1 |
| West Germany | | 1 |
| total | 165 | 230 |
| final total | 4757 | 4682 |

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# Academic Calendar

The university academic calendar has evolved over the years to reflect the desires of students and faculty and the needs of the university as a whole.

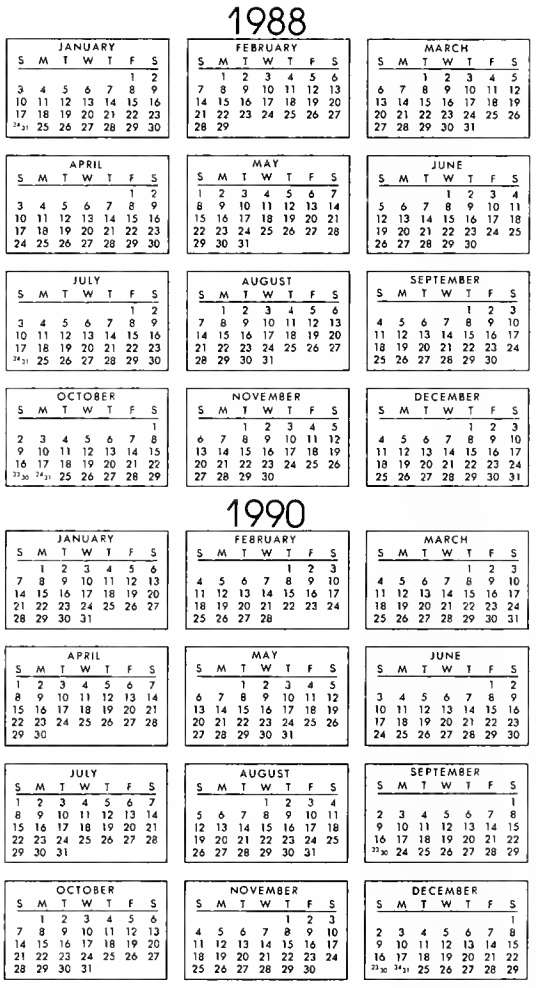
Generally speaking, classes are scheduled only Monday through Friday. Typically, a three-credit-hour course is offered with either three fifty-minute class sessions Monday, Wednesday, and Friday morning, or with two seventy-five minute classes on Tuesday and Thursday morning. Afternoon classes Monday through Friday are scheduled in either fifty-minute or seventy-five minute segments.

Students should note that the fall semester concludes prior to the holiday vacation in December. To make this possible, classes commence at the end of August. In the spring semester, classes begin following the semester break, and conclude in mid-May.

While every effort has been made to include correct dates in the calendar that follows, the faculty or the University Forum may exercise their right to make changes.

## Spring, 1989

**March 1** (Wednesday)—Last day for filing application for June graduation; four o'clock quizzes
**March 13** (Monday)—Midsemester reports due
**March 29** (Friday)—Last day to withdraw with a 'W'; Monday classes meet
**March 18** (Saturday)—Spring vacation begins
**March 28** (Tuesday)—Spring vacation ends (7:45 a.m.)
**April 11** (Tuesday)—Four o'clock quizzes
**April 12** (Wednesday)—Four o'clock quizzes
**April 13** (Thursday)—Four o'clock quizzes
**April 18** (Tuesday)—Four o'clock quizzes
**April 20-21** (Thursday and Friday)—Pacing Break
**April 24** (Monday)—Classes resume
**May 5** (Friday)—Last day for June doctoral candidates to deliver approved dissertation drafts; last day of classes
**May 8-9** (Monday and Tuesday)—Review-Consultation-Study period
**May 10** (Wednesday)—Final examinations begin
**May 19** (Friday)—Final examinations end
**May 22** (Monday)—Last day for June doctoral candidates to complete all degree requirements
**May 30 - August 18**—Summer Sessions
**June 4** (Sunday)—University Day (commencement)



## Summer, 1989

### *First Session*

**May 22-26**—Graduate registration
**May 30** (Tuesday)—Undergraduate registration, last day for graduate registration
**May 30 - July 6**—Classes in session
**June 2** (Friday)—Monday classes meet
**June 9** (Friday)—Tuesday classes meet
**July 7-8** (Friday and Saturday)—Course examinations

### *Second Session*

**July 3, 5-7**—Graduate registration
**July 10** (Monday)—Undergraduate registration, last day for graduate registration
**July 10 to August 17**—Classes in session
**August 18-19** (Friday and Saturday)—Course examinations

## Fall, 1989

**August 21-25** (Monday to Friday)—Graduate registration
**August 25-27** (Friday to Sunday)—Freshman orientation
**August 28** (Monday)—Undergraduate Registration
**August 29** (Tuesday)—First day of classes; last day for graduate registration
**September 1** (Friday)—Last day of filing application for Founder's Day degree
**September 11** (Monday)—First faculty meeting of the academic year. Last day for fall registration and adding courses.
**September 28** (Thursday)—Four o'clock quizzes
**October 3** (Tuesday)—Four o'clock quizzes
**October 4** (Wednesday)—Four o'clock quizzes
**October 5** (Thursday)—Four o'clock quizzes
**October 7-10** (Saturday to Tuesday) Pacing Break
**October 8** (Sunday)—Founder's Day
**October 11** (Wednesday)—Monday classes meet
**October 16** (Monday)—Midsemester reports due
**October 23** (Monday)—Preregistration begins
**October 27** (Friday)—Preregistration ends
**November 1** (Wednesday)—Last day to withdraw from a course with a 'W"
**November 2** (Thursday)—Four o'clock quizzes
**November 7** (Tuesday)—Four o'clock quizzes
**November 8** (Wednesday)—Four o'clock quizzes
**November 9** (Thursday)—Four o'clock quizzes
**November 23-26** (Thursday to Sunday)—Thanksgiving vacation
**November 27** (Monday)—Classes resume
**December 8** (Friday)—Last day of classes
**December 9-12** (Saturday to Tuesday)—Review-consultation-study period
**December 12** (Tuesday, 4:00 p.m.)—Course examinations begin
**December 23** (Saturday, noon)—Course examinations end

## Spring, 1990

**January 8-12** (Monday to Friday)—Graduate registration
**January 14** (Sunday)—Commencement
**January 15-16** (Monday and Tuesday)—Undergraduate registration
**January 17** (Wednesday)—First day of classes; last day for graduate registration
**January 30** (Tuesday)—Last day for spring registration and adding courses
**February 14** (Wednesday)—Four o'clock quizzes
**February 15** (Thursday)—Four o'clock quizzes
**February 17-19** (Saturday to Monday)—Pacing Break
**February 20** (Tuesday)—Four o'clock quizzes
**February 21** (Wednesday)—Monday classes meet
**February 22**(Thursday)—Four o'clock quizzes
**March 1** (Thursday)—Last day to apply for June graduation
**March 2** (Friday)—Midsemester reports due
**March 10-18** (Saturday to Sunday)—Midsemester Break
**March 28** (Wednesday)—Last day to withdrawn from a course with a 'W'
**March 29** (Thursday)—Four o'clock quizzes
**April 3** (Tuesday)—Four o'clock quizzes
**April 4** (Wednesday)—Four o'clock quizzes
**April 5** (Tuesday)—Four o'clock quizzes
**April 12-15** (Thursday to Sunday)—Easter Break
**April 16** (Monday)—Preregistration begins
**April 20** (Friday)—Preregistration ends
**May 4** (Friday)—Last day of classes
**May 5-8** (Saturday to Tuesday)—Review-consultation-study period
**May 8** (Tuesday, 4:00 p.m.)—Final examinations begin
**May 19** (Saturday, noon)—Final examinations end
**June 2** (Saturday)—University Day (commencement)

# LEHIGH UNIVERSITY

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